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Croatian Association for Construction Management
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15TH INTERNATIONAL CONFERENCE ORGANIZATION, TECHNOLOGY AND MANAGEMENT IN CONSTRUCTION

AND

6TH INTERNATIONAL PROJECT MANAGEMENT ASSOCIATION SENET CONFERENCE

CONFERENCE PROCEEDINGS

Cavtat (Dubrovnik), September 21 - 24, 2022 Croatia

The 15th International Conference on Organization, Technology and Management in Construction 2022 and the 6h IPMA Research Conference 2022 have been financially supported by the Ministry of Science and Education of the Republic of Croatia.

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SVEUČILIŠTE U ZAGREBU GRAĐEVINSKI FAKULTET
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Foreword

Dear Colleagues, dear Friends,

On behalf of the Organizing Committee, it is our great pleasure to welcome you to the 15th OTMC, International Conference and 6th IPMA SENET Conference. This time we meet again to share new knowledge in the field of organization, technology and management in construction, but also on actual topics in project management.
The four keynote lectures, given by distinguished authors, will lead us into actualities from the field of the conference. During the parallel sessions we will have opportunity to hear and discuss presentations of 59 peer reviewed papers authored by more than 200 researchers and professionals from 30 countries.
The conference will also provide numerous academic and other related activities. We need to specially mention workshop on publishing in high impact factor journals, which is designed to help young researchers in dissemination of their results. Also, we highlight IPMA Council of Delegates meeting with participation of top-class experts.
Beside scientific and academic content, the conference will host the discussion panel on good practices in Croatian Construction Project Management Practice with participation of eminent professionals and large clients.
We would like to express our thanks to the patrons of the conference. Furthermore, we thank to the sponsors and all of the partners for their generous support for making this conference successful.
We wish you all productive participation at the Conference, establishing many new contacts and having a pleasant stay in Cavtat and Croatia.

Yours Sincerely,

Prof. Dr. Ivica Završki
OTMC 2022, Chairman and the General Conference Chair

Prof. Dr. Mladen Vukomanović
IPMA SENET 2022, Chairman

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Development of Dynamic Site Layout for Production Hall

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Abstract:

As BIM becomes the predominant technology in construction industry, contractors, amongst other activities, need to develop dynamic site layout. 3D and 4D BIM modelling are important steps towards developing BIM models ready for construction execution phase. Currently there is a scarcity of standards, studies and research which would guide contractors in developing of dynamic site layout. In this study we addressed this problem by employing case-study method and define input data and steps when developing dynamic site layout. The results show that the following input data is needed: hierarchically structured 3D BIM model, WBS, detail schedule for construction phase, resources constraints and defined onsite temporary facilities. Also, we have found development of dynamic site layout in BIM environment includes three steps: temporary facilities and storage spaces placement; schedule definition for site logistics planning and resources assignment; 4D BIM modelling and dynamic site layout extraction. Our results enable contractors to create dynamic site layout according to the BIM principles.

Keywords: *dynamic site layout; 3D BIM model; 4D BIM model; level of detail*

1. Introduction

Site logistics planning (SLP) and construction site layout planning (CSLP) are crucial activities for contractors during mobilization and construction project phases because logistics costs represent a substantial share of the project total cost (Song et al., 2019; Hammad, 2020; Whitlock et al., 2021; Kolarić et al., 2022; Dahlin and Pesämaa, 2021). As BIM becomes the predominant technology trend in construction industry, contractors start applying it to usual activities such as SLP. BIM tools that enable SLP fall into two categories – 3D BIM (e.g., Revit, Allplan, Tekla) and 4D BIM tools (e.g., Synchro 4D, Vico Office, Navisworks, Bexel Manager) (Schwabe et al., 2016; De Gaetani et al., 2020).

3D BIM software enables creation of the static layout models which assume that all components (e.g., equipment, temporary facilities) of BIM model exist through the entire duration of the construction and that all components have fixed position on the construction site (Kumar and Cheng, 2015). Thus, 3D BIM tools have limited functions for the supply chain analysis due to the inability to link construction schedule activities with elements of the BIM model (Jupp, 2017; Astour and Franz, 2014; Vycital and Jarský, 2020). Static layout models are created using available object libraries (e.g., equipment libraries, libraries of temporary facilities) from which BIM site objects are imported in 3D BIM model (Schwabe et al., 2016; Jupp, 2017; Cassano and Trani, 2017).

Furthermore, 4D BIM software can be dived in two categories – construction planning and site planning (Jupp, 2017). 4D BIM software for construction planning include functions for (Jupp, 2017; Tserng et al., 2014; Abbasi et al., 2020; Wang et al., 2020; Marzouk and Daoor, 2018):

- Construction activities analyses
- Construction schedule definition
- Schedule optimization
- Resources management and allocation
- Resources utilization calculation
- Workspace planning
- Construction monitoring; as-built schedule management
- Safety planning
- Labor evacuation planning
- Tact-time calculation
- Visualization of project construction

4D BIM software for site planning enables creation of the dynamic layout models which consider the actual duration for which temporary facilities and equipment are required on the construction site during different phases of construction (Kumar and Cheng, 2015; Kolarić et al., 2022). Also, dynamic layout models integrate construction schedule and 3D model data based on scope quantification, supply chain management, storage space analyses and work-space conflict detection (Kumar and Cheng, 2015; Yu et al., 2016; Zolfagharian and Irizarry, 2014; Ma et al., 2020). 4D BIM tools for site planning have functionalities for (Jupp, 2017; Sloot et al., 2019; Heesom et al., 2003; Bortolini et al., 2015; Wang et al., 2015; Cheng and Kumar, 2014; Razavialavi et al., 2014; Kassem et al., 2015; Cheng and Kumar, 2015; Sulankivi et al., 2010; Sulankivi et al., 2009; Ning and Guangbin, 2019; Getuli et al., 2016; Mihić et al., 2019; Cao et al., 2021):

- Inspection of workflow (4D) clashes
- Managing site logistics
- Calculation of storage and accommodation capacities
- Supply chain visualization
- Resource management
- Safety planning and analyses
- Off-site and on-site logistics coordination
- Suppliers and subcontractors coordination

Current literature is largely intended for possible users, not for actual ones because many authors analyze advantages of 4D BIM usage in site planning domain. Therefore, numerus problems have been identified when using BIM tools for CSLP (e.g., using of 4D BIM tools for analyzing specific activities on the construction site; placing of site elements and placement optimization; construction resources allocation and optimization; level of detail of construction resources; different level of detail in construction schedule, BOQ, BOM and 3D model when developing 4D and 5D BIM models; changes of the level of detail of construction schedule, building model and construction resources during different project phases; difference between level of detail of building model when it is used for design development and SLP (in the same project phases).

The problem of this research was that currently there is a scarcity of standards, studies and research which would guide contractors in developing of dynamic site layout in the BIM environment. This paper aims to define input data and step to allow assessing dynamic site layout designs in the BIM environment. In doing so, this paper is organized in a few sections. In the next section methodology of the research is presented. Results of the research are presented in the section three, while in the last section we provide conclusions.

2. Methodology

For this research we used case-study method to understand how 4D BIM model should be prepared to enable site logistics planning and dynamic site layout creation. Case-study research is the suitable method to understand the complexity of the problem connected with lack of standardization, when using BIM tools for site logistics planning. Research was conducted in the two steps. First step was definition of input data, while second step was development of dynamic site layout in the BIM environment.

The project selected for this case-study was the production hall in Kutina, city of Croatia. The hall area was 1625 m^2 while construction site area was 6000 m^2. Further, production hall was dived into three functional areas – offices, production plant and warehouse, and consisted of monolithic reinforced concrete parts, prefabricated steel construction, panels (roof and facade) and drywall system.

3. Results

3.1. Input data for dynamic site layout development in the BIM environment

The preparation for construction works included four activities: 3D BIM model design; Work Breakdown Structure (WBS) and detail construction schedule development; and construction site equipment definition. Thus, 3D BIM model, WBS, detail construction schedule and re-sources constraints were input materials for site logistics planning in the BIM environment and need to be analyzed before starting with 4D modeling and site planning.

3D BIM model was designed in BIM authoring software Nemetschek Allplan (Figure 1). Data in 3D BIM model were segregated as follows: project (production hall), buildings (offices, production plant, warehouse), floors (foundations, ground floor, first floor and roof - offices; foundations, ground floor and roof - production plant and warehouse) and construction elements (slab foundations, steel columns, steel beams, L-profile facade panels, roof frame rafter, roof purlin, roof bracing, roof panels - offices, production plant and warehouse; slab, stairs and partition walls - offices).

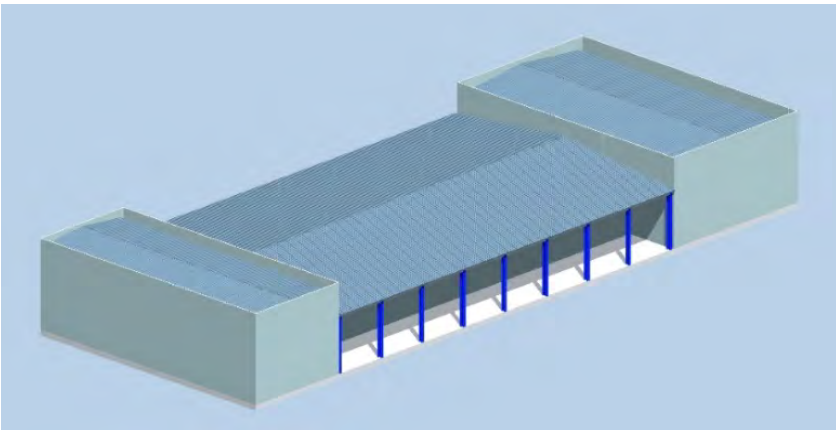

Figure 1. 3D model of production hall

WBS (Table 1) was developed in six levels which were in line with the data segregation in the 3D BIM model: project (level 1), work type (level 2), group of works (level 3), floor (level 4), construction element (level 5) and activities (level 6).

Table 1. WBS for construction phase and detail schedule for construction phase

WBS LEVEL NAME	DURATION
PRODUCTION HALL	**60d**
1. SITE PREPARATION WORKS	**8d**
1.1. MATERIAL DELIVERY	8d
1.1.1. FORMWORK DELIVERY	1d
1.1.2. REINFORCEMENT DELIVERY	3d
1.1.3. STEEL CONSTRUCTION DELIVERY	1d
1.1.4. FACADE PANELS DELIVERY	1d
1.1.5. ROOF PANELS DELIVERY	2d
2. CONSTRUCTION WORKS	**58d**
2.1. OFFICES	38d
2.1.1. FOUNDATIONS	5d
2.1.1.1. SLAB FOUNDATIONS	5d
2.1.1.1.1. FORMWORK AND REINFORCEMENT INSTALLATION	2d
2.1.1.1.1. CONCRETE WORKS	1d
2.1.1.1.1. FORMWORK DISMANTLING	1d
2.1.2. GROUND FLOOR	34d
2.1.2.1. STEEL COLUMNS	4d
2.1.2.1.1. ASSEMBLY	4d
2.1.2.2. STEEL BEAMS	2d
2.1.2.2.1. ASSEMBLY	2d
2.1.2.3. L-PROFILE	1d
2.1.2.3.1. ASSEMBLY	1d
2.1.2.4. SLAB AND STAIRS	12d
2.1.2.4.1. FORMWORK AND REINFORCEMENT INSTALLATION	4d
2.1.2.4.2. CONCRETE WORKS	1d
2.1.2.4.3. FORMWORK DISMANTLING	2d
2.1.2.5. FACADE PANELS	2d
2.1.2.5.1. ASSEMBLY	2d
2.1.2.6. PARTITION WALLS	8d
2.1.2.6.1. ASSEMBLY	8d
2.1.3. FIRST FLOOR	3d
2.1.3.1. STEEL COLUMNS	2d
2.1.3.1.1. ASSEMBLY	2d
2.1.3.2. STEEL BEAMS	1d
2.1.3.2.1. ASSEMBLY	1d
2.1.4. ROOF	7d
2.1.4.1. ROOF FRAME RAFTER	1d
2.1.4.1.1 ASSEMBLY	1d
2.1.4.2. ROOF PURLIN	2d
2.1.4.2.1. ASSEMBLY	2d
2.1.4.3. ROOF BRACING	1d
2.1.4.3.1. ASSEMBLY	1d
2.1.4.4. ROOF PANELS	3d
2.1.4.4.1. ASSEMBLY	3d
2.2. PRODUCTION PLANT	56d

2.2.1. FOUNDATIONS	13d
2.2.1.1. SLAB FOUNDATIONS	13d
2.2.1.1.1. FORMWORK AND REINFORCEMENT INSTALLATION	10d
2.2.1.1.2. CONCRETE WORKS	2d
2.2.1.1.3. FORMWORK DISMANTLING	2d
2.2.2. GROUND FLOOR	40d
2.2.2.1. STEEL COLUMNS	4d
2.2.2.1.1. ASSEMBLY	4d
2.2.2.2. STEEL BEAMS	3d
2.2.2.2.1. ASSEMBLY	3d
2.2.2.3. L-PROFILE	1d
2.2.2.3.1. ASSEMBLY	1d
2.2.2.4. FACADE PANELS	3d
2.2.2.4.1. ASSEMBLY	3d
2.2.3. ROOF	25d
2.2.3.1. ROOF FRAME RAFTER	2d
2.2.3.1.1. ASSEMBLY	2d
2.2.3.2. ROOF PURLIN	4d
2.2.3.2.1. ASSEMBLY	4d
2.2.3.3. ROOF BRACING	1d
2.2.3.3.1. ASSEMBLY	1d
2.2.3.4. ROOF PANELS	3d
2.2.3.4.1. ASSEMBLY	3d
2.3. WAREHOUSE	13d
2.3.1. GROUND FLOOR	13d
2.3.1.1. STEEL COLUMNS	2d
2.3.1.1.1. ASSEMBLY	2d
2.3.1.2. STEEL BEAMS	2d
2.3.1.2.1. ASSEMBLY	2d
2.3.1.3. L-PROFILE	1d
2.3.1.3.1. ASSEMBLY	1d
2.3.1.4. FACADE PANELS	2d
2.3.1.4.1. ASSEMBLY	2d
2.3.2. ROOF	7d
2.3.2.1. ROOF FRAME RAFTER	1d
2.3.2.1.1. ASSEMBLY	1d
2.3.2.2. ROOF PURLIN	2d
2.3.2.2.1. ASSEMBLY	2d
2.3.2.3. ROOF BRACING	2d
2.3.2.3.1. ASSEMBLY	2d
2.3.2.4. ROOF PANELS	2d
2.3.2.4.1. ASSEMBLY	2d
3. SITE DEMOBILIZATION WORKS	**1d**
3.1. MATERIAL AND EQUIPMENT REMOVAL	1d
3.1.1. AUTO CRANE DEPARTURE	2d
3.1.2. FORMWORK REMOVAL	1d

Activities for construction schedule development were defined in the last level of WBS. Each activity had belonging duration, predecessors, and successors. Estimated duration of site preparation, construction, and site demobilization works was 60 days (Table 1). Detail construction schedule was developed in the software Bentley Synchro PRO.

Types of resources which were consider in this paper were materials, machinery, temporary facilities, and storage spaces. Access to the construction site was provided by the existing road while on the construction site are planned internal traffic routes for machinery operating on the construction site. Necessary temporary facilities are security huts, concrete barrier, security fencing, toilets, and site cabins, while necessary onsite storage spaces are for storage of formwork, reinforcement, parts of steel construction, facade panels, and roof panels.

3.2. Steps for dynamic site layout development in the BIM environment

Dynamic site layout was developed through the three steps: temporary facilities and storage spaces placement, schedule definition for site logistics planning in the BIM environment and resources assignment, and 4D modeling and dynamic site layout extraction.

Necessary temporary facilities and storage spaces are placed on the construction site according to the general guidelines for site planning used in the Croatian market (Radujković et al., 2015). Preconditions for further site planning is shown on the Figure 2.

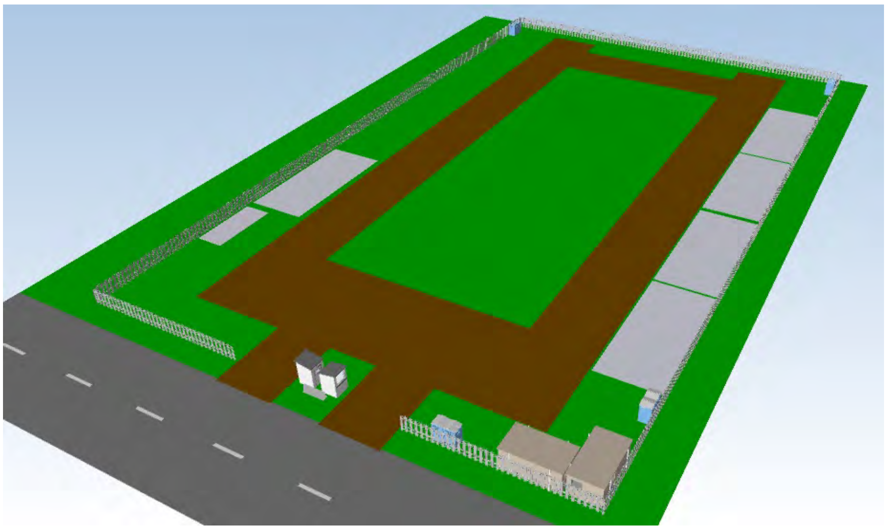

Figure 2. Positions of temporary facilities and storage spaces on the construction site

Detail construction schedule for site logistics planning in BIM environment was developed based on the detail schedule for construction phase defined generalized activities listed in Table 2. Activities in detail schedule for construction phase were divided more in detail to enable machinery and activities assignment to 3D paths (trajectories of machinery movement), but also material handling simulation on the construction site. In other words, each activity defines one work operation.

Table 2. Activities used for detail schedule for dynamic site layout development

WBS LEVEL	ACTIVITIES	MATERIALS	MACHINERY
1. MATERIAL DELIVERY	1.1. Truck arrival	Material on the truck	Truck
	1.2. Forklift positioning for unloading		Forklift
	1.3. Truck stop (during	Material disappears from the	Truck

	unloading)	truck	
	1.4. Forklift repositioning (during unloading)	Material on the forklift Material appears on the stock	Forklift
	1.5. Truck departure		Truck
2. FORMWORK AND REINFORCEMENT INSTALLATION	2.1. Formwork installation	Material appears on the place of the future element Material disappears from the stock	
	2.2. Reinforcement installation	Material appears on the place of the future element Material disappears from the stock	Mobile crane
3. CONCRETE WORKS	3.1. Truck concrete pump arrival		Truck concrete pump
	3.2. Truck mixer arrival		Truck mixer
	3.3. Truck mixer and truck concrete pump stop (concrete works)	Material appears on the place of the future element	Truck mixer Truck concrete pump
	3.4. Truck concrete pump departure		Truck concrete pump
	3.5. Truck mixer departure		Truck mixer
4. FORMWORK DISMANTLING	4.1. Formwork dismantling	Material appears on the stock	
5. ASSEMBLY (with machinery)	5.1. Mobile crane positioning		Mobile crane
	5.2. Forklift repositioning for assembly		Forklift
	5.3. Mobile crane stop (during assembly)	Material appears on the place of the future element	Mobile crane
	5.4. Forklift repositioning (during assembly)	Material on the forklift Material disappears from the stock	Forklift
6. ASSEMBLY (without machinery)	6.1. Element assembly	Material appears on the place of the future element Material disappears from the stock	
7. ASSEMBLY (Just-in-Time material delivery)	7.1. Truck arrival	Material on the truck	Truck
	7.2. Truck stop (during unloading)	Material disappears from the truck	Truck
	7.3. Truck departure		Truck
	7.4. Element assembly	Material appears on the place of the future element	
8. MATERIAL REMOVAL	8.1. Truck arrival	Material on the stock	Truck
	8.2. Forklift positioning for loading		Forklift
	8.3. Truck stop (during loading)	Material appears on the truck	Truck
	8.4. Forklift repositioning (during loading)	Material on the forklift Material quantity disappears from the stock	Forklift
	8.5. Truck departure	Material on the truck	Truck

3D BIM elements of production hall which are built during the specific activity execution have been assigned to the appropriate activities in detail construction schedule for the site logistics planning. Beside the 3D BIM elements of production hall, the material resources and machinery which are utilized during execution of the specific activities have also been assigned to the activities according to the Table 2.

When simulating construction of elements, material handling and machinery movements additional properties and settings were implemented (appearance profile and growth simulation) (Figure 3). Elements whose construction is in progress were highlighted with the green color, but when activity was finished all assigned elements appeared in the real colors. Growth simulation depended on the specific element (e.g., for slab is left-right). Further, start and active appearance for materials depended on the material type (blue for formwork, steel construction and panels, red for reinforcement), while end appearance was original color.

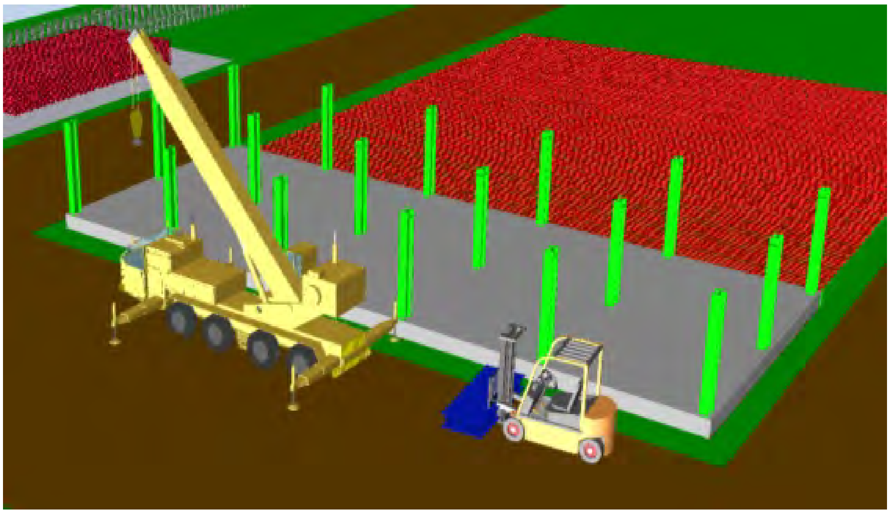

Figure 3. Appearance profile and growth simulation setup

Finally, to define trajectories of movement of materials and machinery, 3D paths were defined, and specific activities and resources were assigned to them (Figure 4). When resource and activity were assigned to the 3D path, specific resource was changing position according to the 3D path line during activity execution.

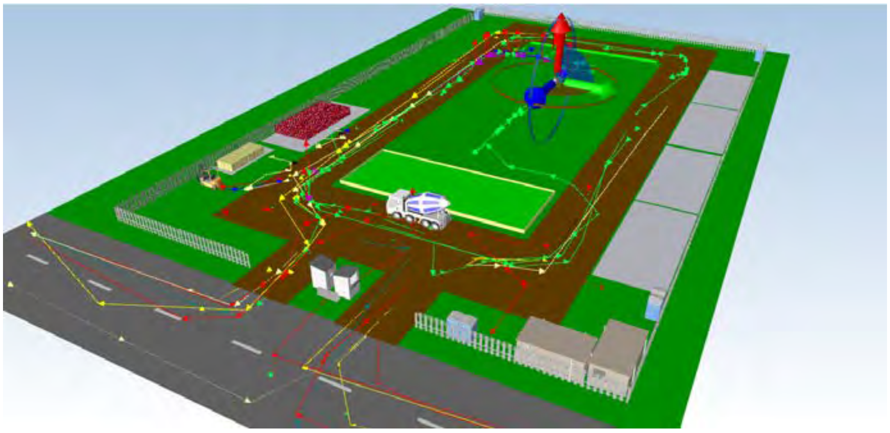

Figure 4. 3D path definition and assignment

When 4D BIM model is created, dynamic site layout should be extracted as video or short clips from the 4D simulation footage.

4. Conclusion

In this paper input data and step to allow assessing dynamic site layout designs in the BIM environment have been defined. Input data for site logistic planning in the BIM environment, are well hierarchically structured 3D BIM model, WBS, detail schedule for construction phase, resources constraints definition as well as defined necessary onsite temporary facilities. Results shown that data in the 3D BIM model should be properly segregated in the levels (project, buildings, floors, construction elements) to enable assignment of 3D objects with appropriate activity in schedule. SLP process in BIM environment includes three steps: temporary facilities and storage spaces placement; schedule definition for site logistics planning and resources assignment; 4D BIM modelling and dynamic site layout extraction. When creating dynamic site layout in the BIM environment growth simulation and 3D path should be defined and assigned to resources. Also, activities in detail construction schedule should be further divided into work operations to enable definition of detail schedule for dynamic site layout development. Following defined steps, contractors can create dynamic site layout according to the BIM principles. Since the research was conducted in very limited conditions, results should be tested in different conditions (e.g., different type of project, different size of project, other BIM authoring tools, other 4D BIM tools, different type of resources, health and safety analyses, more complex internal traffic routes).

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Digitalizing Building’s End-of-Life

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Abstract:

The end-of-life phase of buildings’ life-cycles is still missing a structured approach that could align digitalization with research and practice in a single flow of topics of interest, within and beyond the phase. Performed processes are often not understood in a larger context. They are not related to each other, despite the growing interest in the architecture, engineering and construction industry, and regulatory bodies aiming to address sustainability. With this research, a framework that can contextualize existing digitalization approaches is provided. Therefore, an overview of tasks performed by three project partners is used to propose a framework. It is conceptualized with lanes describing the actors, processes, and assets, and further divided into two parallel lanes dealing with physical and digital assets; the framework is verified with business models, research papers, projects, and regulations. It encompasses existing processes and provides a structured, high-level overview. This research serves as a base for defining relevant factors for each step of the end-of-life phase, required to determine the influence matrix needed for clarification of existing and future business models concerning both physical and digital assets in the phase of interest. The provided structured overview will be used to determine obstacles and potentials in the end-of-life phase, and overreaching influence on domains like circular economy, building planning or ecological performance.

Keywords: *end-of-life; building; digitalization; framework; physical assets; digital assets; BIM*

1. Introduction

Waste reduction is one of the priorities of the European Union (EU) and a principle (as part of the waste hierarchy) of the waste framework directive (WFD), regulating the waste definition and the general handling of waste, as well as goals to reach (EU, 2008). It directly corresponds to four sustainable development goals defined by the United Nations (UN): goal 9 - Industry, Innovation, and Infrastructure, goal 11 - Sustainable Cities and Communities, goal 12 - Responsible Consumption and Production, and goal 13 - Climate Action, and indirectly affects several more (UN, 2022). Goals 9, 11, 12, and 13 have middle to strong interaction with each other, as shown by van Soest *et al.* (2019); similarly, Bleischwitz *et al.* (2018) focus on the goals 2, 6, 7, 11, and 12 including energy, water, food, land and material, and their interconnection to propose a resource nexus. UN goals emphasize the importance of waste reduction. Waste in the architecture, engineering and construction (AEC) industry makes up a third of all waste produced in the EU (construction and demolition waste (CDW) infrastructure). It is worth mentioning that there is a high degree of divergence within the individual member states.

Disposal of waste may lead to loss of material and energy (Antunes *et al.,* 2021) and needs to be reduced to a necessary minimum to improve sustainability. Resources such as energy, materials, and building elements, can be considered for further use after their primary use has been terminated. A high-level framework could encompass handling different resources due to similar trends to minimize waste. Economic gains are often in a gray zone due to process complexity (Pun *et al.,* 2006), and incentives could drive new, more sustainable approaches in the future and encourage them in practice. Essential questions about the reuse of building materials also encompass legislative and market barriers, lack of economic driving forces, and no information about used construction products (Nordby, 2019). From the national economic point of view, it makes sense to promote high-quality end-of-life (EoL) processes because of the increased employment and value added (EC, 2014; Meyer *et al.,* 2018).

The EoL phase of buildings' life-cycles is still underinvestigated. However, it has become a popular topic across the AEC industry lately. Research and industry aim to reduce the amount of CDW, having the largest share of the total waste across different sectors. Numerous studies deal with various aspects of digitalization of that phase (Cetin *et al.,* 2021), such as building geometry scanning using LIDAR, relations to BIM, new business models, or assessing building stocks. Activities leading to reuse, recycling, or disposing CDW have existed for a long time with lower digitalization levels and varying efficiency. The digitalization of a building's EoL tends to increase recycling and reuse at the expense of disposal, and in that way reduce the production of waste. However, various EoL activities are being digitalized at once, making it difficult to position the existing practices, research, and tools in the EoL ecosystem. Detailed analysis of the supply chain and projects is needed for achieving Integrated Design & Delivery Solutions, which is seen as the next step in the digitalization of the AEC industry (Owen *et al.,* 2009). A structured overview of the phase is missing, which could integrate traditional and novel practices, pinpoint the gaps, and provide a base for regulations and novel solutions. The main goal of this paper is to provide a structured framework for the EoL of buildings, which considers both digital and physical aspects of the phase. A suitable framework should serve to improve the CDW management in the long term.

2. Existing EoL Frameworks

The EoL phase of assets is the least sustainable phase (Charef *et al.,* 2021), and it is hard to grasp from the practice perspective as well as research. It often involves topics such as the creation of a BIM model or simply BIM, design for reuse, design for deconstruction and disassembly. These are common processes of a design phase, as well as the reuse of one or more building elements in the novel building, and high-quality waste management which already belongs to the next life of CDW (Akbarieh *et al.,* 2020; Akinade *et al.,* 2017; Charef and Lu, 2021). The EoL phase occurs for each unique product and may take place multiple times during the building's life-cycle (Figure 1), ending in a final EoL phase when the building is demolished. To reduce the CDW, existing tendencies direct the use of CDW produced during various EoLs towards new service, within the building construction and beyond (Figure 1 - b). Currently, the most popular practices still direct the CDW toward the deposition (Figure 1 - a). An essential factor that should decrease CDW disposal is the digitalization of buildings´ life cycles (Cetin *et al.,* 2021) and hence EoL phase.

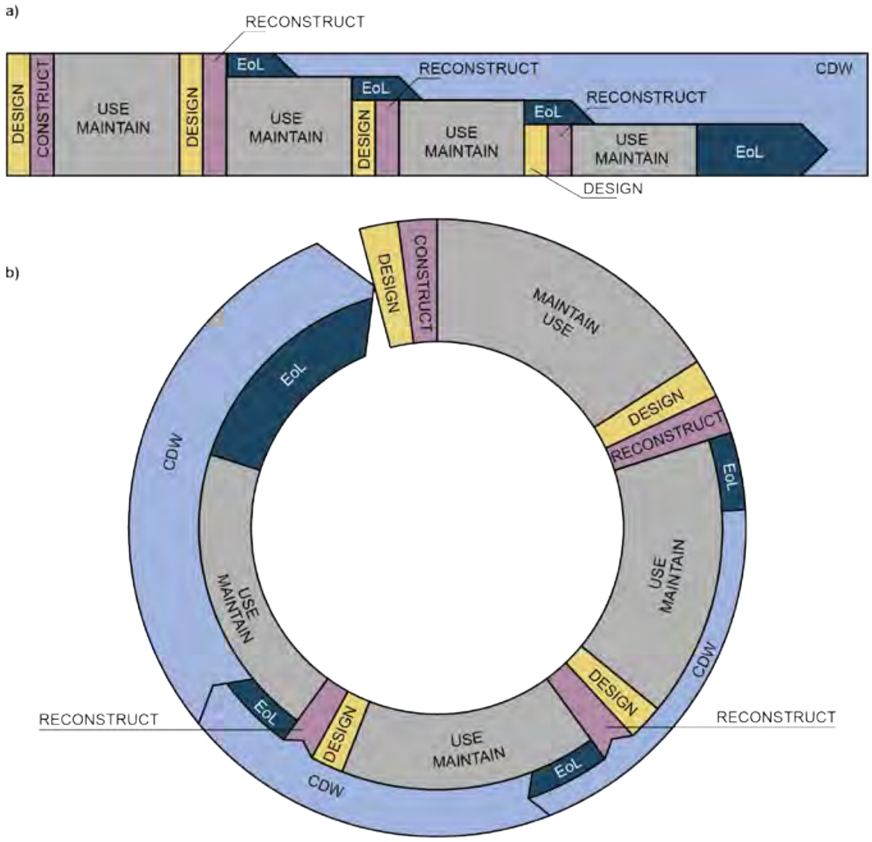

Figure 1 Schema of the EoL phase in a) linear and b) circular construction process (inspired by Bjork, 1999)

It is crucial to identify what the system limits of the EoL phase are to investigate it. Giorgi *et al.* (2018) present various approaches toward the life-cycle assessment, stating many uncertainties regarding its scope, as it occures in the future where large amounts of data are required for its achievement. Therefore, a unified, transparent data basis is crucial (EU, 2019). Based on Giorgi *et al.* (2018) EoL starts with the activity that produces waste and involves waste management. In EN 15978 (CEN, 2011) EoL is a “multi-output process that provides a source of materials, products and building elements that are to be discarded, recovered, recycled or reused”. This includes all the processes and the transport to the waste's final destination (EC, 2018).

Used metrics for the EoL phase are vague and may display the phase as less relevant in the whole life-cycle of a building. For instance, EN 15978 (CEN, 2011) proposes a cut-off approach, and thereby the benefits of a “new life” are not distributed to the EoL (Giorgi *et al.,* 2018). The basic framework for the EoL is EN 15643 (Austrian Standards, 2021), the relevant data in the form of EPDs ISO 14025 (ISO, 2006) in general, and EN 15978 (CEN, 2011) for buildings, and for building materials and products EN 15804 (CEN, 2019). It should be noted that the establishment of recycling, recovery and reuse does not necessarily lead to a reduction of environmental impacts, as shown by (Andersen, 2020; Demacsek, 2019).

Lopez Ruiz *et al.* (2020) propose a framework focusing on physical aspects of five life-cycle stages, but not aligning it to digitalization attempts. In their work, the EoL phase involves different types of deconstruction or demolition of buildings, is preceded by construction and building renovation, and followed by collection and distribution. Schutzenhofer *et al.* (2022) develop a framework for EoL based on the existing regulations in

Austria, and identify data requirements for CE calculations. Similarly, Yeheyis *et al.* (2013) developed a framework as a decision-help for reducing waste disposal, focused on the practices in Canada, based on environmental, social and economic indicators. BIM for various scenarios in EoL is investigated in Charef (2022). She identifies several models of how BIM can be used in the EoL phase, and emphasizes the need to consider the EoL at the project start. Akbarieh *et al.* (2020) provide a review of BIM supports for EoL, stating that a global framework is required for the uptake of more sustainable and circular buildings. Cetin *et al.* (2021) provide a Circular Digital Built environment framework and align it with multiple technologies. They align various digital solutions within the proposed framework, however the research scope is not focused solely on the EoL phase, which is not investigated in detail, nor the tasks within it.

As already identified in the literature, a global framework for the EoL phase is required. The novelty of our framework is on one side that we focus on the EoL phase and determine its limits. On the other side, we consider both digital and physical processes, as well as their alignment regarding the actors, processes and assets. A similar framework was not found in the literature. We find such framework to be necessary, for the future development of the EoL phase and further better understanding of existing practices and business models, intending to identify its enhancement potential.

3. Methodology

This paper aims to form a framework for positioning and evaluating the EoL phase in the AEC industry. The framework is conceptualized based on two research papers. Succar and Poirier (2020) propose a complex global framework for life-cycle information transformation and exchange. The framework aims to cover a great scope of possible scenarios in the AEC industry, with various scales, information flows, automation potential, etc. The scope of the herein presented research is solely the EoL phase of buildings. We concentrate on the deliverables or assets as described in Succar and Poirier (2020), which can be digital and physical, being interrelated in multiple ways. Sibenik *et al.* (2022) describe a 3A methodology for activity patterns that capture assets, activities and actors, with the aim to digitalize design workflows. These two approaches are combined to capture physical and digital assets, activities and actors within the EoL phase on a high level with less granularity. The captured processes are therefore not necessarily on the atomic level as described in Sibenik *et al.* (2022), and will remain named processes, as they may consist of multiple activities. The resulting lanes are produced via an introductory meeting with the consortium members of the project DiCYCLE. The consortium includes three companies dealing with different processes in the EoL phase who described their workflows and tasks in a nutshell. The meeting outcomes and consideration of the research papers mentioned above resulted in an initial framework structure.

After the framework setup, six lanes describing the EoL phase were generated (Figure 2). The verification of the framework model is applied to seven different business models (BMs) in the companies of the project partners, four research papers, seven regulations and four research projects. This verification is performed in order to (1) identify the activities currently performed in the EoL phase, (2) assess if the model is suitable to cover all the tasks and finally (3) fitting for understanding the roles of particular stakeholders and the assets of interest. The verification of business models is performed by sending a questionnaire to the corresponding experts familiar with these activities. The questionnaires were followed by three phone interviews. Scope and topics which the research covers is allocated in the proposed framework model. Afterwards, the results are mapped into the proposed process flows, considering actors and assets based on the inputs of project partners. Following the verification, possible improvements are concluded.

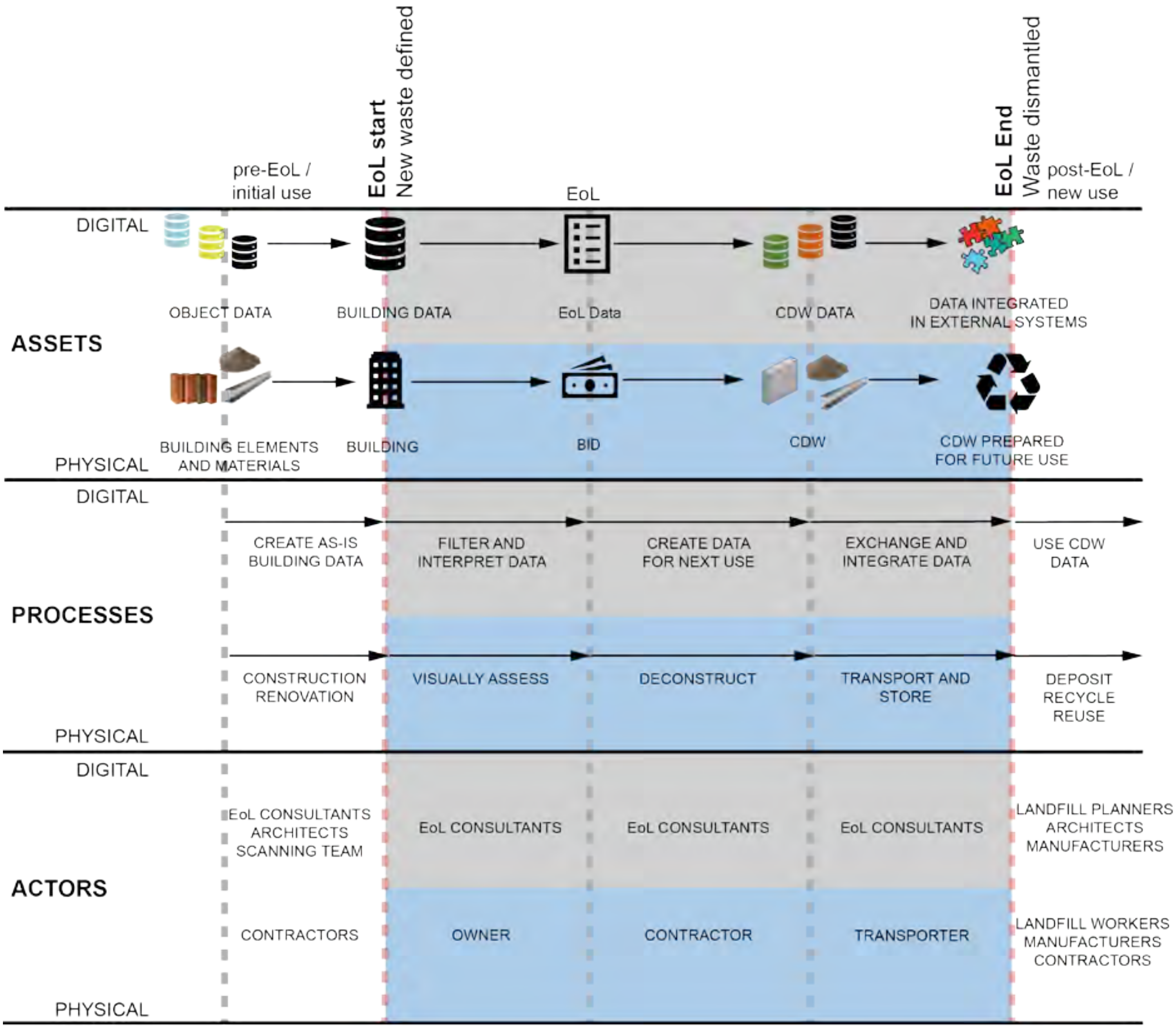

Figure 2 Framework for EoL phase

4. Results

The resulting framework is represented on Figure 2. It describes six lanes, including assets, processes and actors, each separated into digital and physical assets. There are several views on the EoL phase. This model aligns physical and digital assets, which means they occur at the same or close to the same moment. Therefore, an as-is BIM is a precondition for the digital support of the EoL phase, in the same way an existing building is a precondition for its deconstruction. A digital building model is used to create EoL data, which corresponds to the creation of bid for deconstruction. These two assets can be related if digital EoL data exists. The following digital asset is filtered CDW data for future use, or in the case of a physical asset, deconstructed CDW. The EoL phase lasts until the physical asset is transported from its existing position, whether on the site or to another construction site or deposition. Accordingly, digital assets are transferred to external system for further data use and management.

Processes dealing with digital and physical assets can take place simultaneously. Still, digital processes may be a precondition for a corresponding physical process, and such topics are described in Succar and Poirer (2020) in a wider scope. Herein the assets are related to each other as milestones, and provide a main organizational delimitators in the framework (vertical dashed lines). Regarding the digital process, preceding the EoL phase is the creation of BIM, which can be performed with numerous technologies, or be obtained from the continuous documentation of BIM from the preceding phases. As the EoL phase starts, the model needs to be filtered and interpreted to create EoL data. This data can be edited for next use, which is exchanged and integrated with other systems in the follow-up. As the data exits the system of the stakeholders responsible for EoL, it belongs to the next use. Parallelly, the physical processes take place. Related to the creation of as-is BIM are all the construction and renovation processes taking place in the building. Traditionally, buildings are visually assessed for deconstruction, thus the CDW next use is determined. Visual assessment is followed by deconstruction and the CDW must be transported and stored afterwards. As it reaches the next use, it does not anymore belong to the EoL phase.

The actors involved in the phase are not clearly defined. Pre-EoL tasks dealing with physical assets are performed by various stakeholders in the building process, mainly contractors. Creation of BIM can originate from architects in the initial building design phase, however, it could be later on generated by EoL consultants or scanning teams. The EoL consultants generally take over digitalization tasks of EoL. At the same time, various physical deconstruction processes involve investors, contractors, and transporters. The stakeholders responsible for the physical assets are affected by the EoL consultant's decisions. As the CDW leaves its primary use, after the EoL phase, various scenarios may take place. Therefore, various new stakeholders may be involved, like landfill planners, architects of new buildings, manufacturers, contractors of new buildings, etc.

5. Verification

Project partners (PP1, PP2 and PP3) activities and businesses represent the first verification step of the novel framework. The project partners were asked to review the proposed framework and provide feedback. All identified tasks performed by the project partners are aligned with the proposed framework in Figure 3. The practices of PP1 are straightforward and result from two business models (BMs). The main BM1 is buying metal waste, sorting it, storing and preparing for recycling to produce secondary raw material. This BM1 belongs to the new life of the material. BM2 is the practice when the PP1 is invited to assess, deconstruct and transport the material found in the building, which is followed by the main BM1. This practice belongs to the EoL phase. Regarding the data management processes, an internal database to record the flow of materials is used when it reaches the facility; building models are not a standard practice.

The PP2 displays a more complex practice involving two BMs. The BM1 of PP2 is mainly consulting regarding the EoL phase, which involves creating of as-is models, filtering and interpreting data for EoL, creating data sets for further use, and data exchange towards external systems. Their BM1 also engages with physical assets of the building, and involves visual inspection of the demolition site, deconstruction and transport and storage, generally on-site. BM2 represents accompanying new constructions with their expertise in using available CDW. Both BMs can be placed in the proposed framework.

The case of PP3 shows the most complex arrangement of the EoL tasks. They are organized as three BMs: BM1 involving visual assessment of physical assets and creating digital assets for next use, like the catalogues of building elements and products. BM2 is dealing with physical deconstruction of the building, transport and storage and arranging the further usage of stored CDW by combined use of digital and physical assets. BM3 involves reuse of data and physical assets in creating new products. Many factors influence CDW being considered and all three BMs, such as time, costs, available quantity and condition of CDW, regulation, idea for reuse, esthetics and functionality.

Literature used to verify the framework is placed within the framework and shown in Figure 3 as well. It involves seven BMs, four research papers, four research projects, and seven regulations.

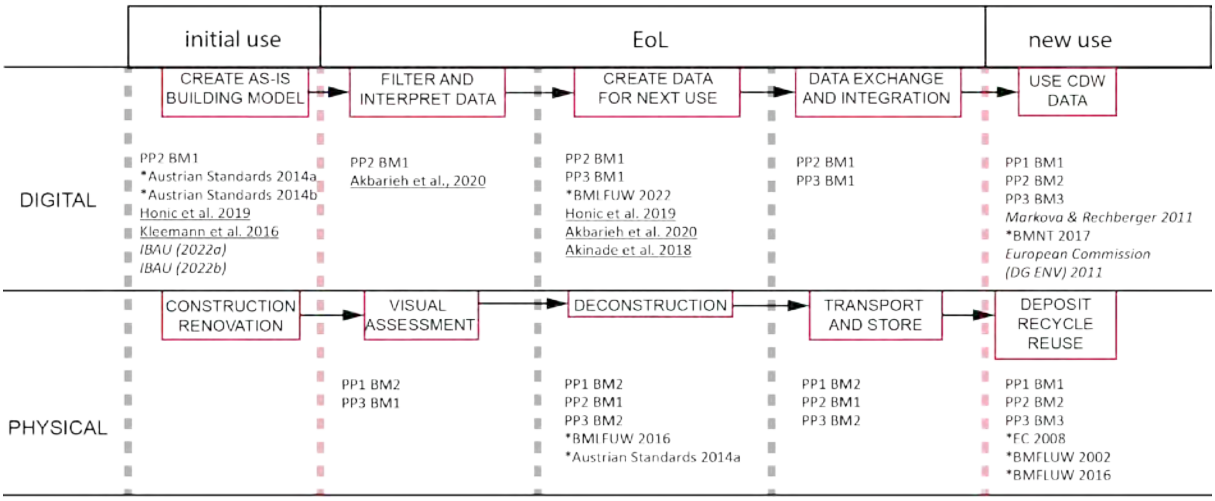

Figure 3 Results of framework verification with BMs: *regulations, research papers, and *projects*

6. Discussion & Conclusion

The examined work, including the practices, literature and projects can be placed in the proposed framework. This work provides a high-level framework to position the digitalization works for the EoL phase. The methodology to establish a framework results from two research papers: one describing a 3A pattern analysis (actor, activity, asset) and another describing the correlation of physical and digital assets. The framework is proposed based on the initial project meetings where the work of project partners was shortly presented. This framework will be used for future research within the project DiCYCLE - Reconsidering digital deconstruction, reuse and recycle processes using BIM and Blockchain.

The verification shows that it is possible to allocate the practices and research within the framework. Asset inputs and outcomes in the framework also correspond the aligned practices and research initiatives. The framework provides a structured EoL phase and will serve to identify gaps in that phase and the factors influencing particular steps in the phase. The need for a similar framework was already recognized in the literature (Akbarieh *et al.*, 2020). The main feature of herein proposed framework is the distinction of digital and physical assets during the EoL phase, which allows for aligning current digital and physical actors, processes and assets, resulting with more clear and exhaustive structure. Existing regulations such as Austrian Standards (2021) or ISO (2006) deliver numerous frameworks for particular topics. However, they mostly neglect some of the stakeholders in the EoL phase. A high-level inclusive framework has not been found. Relation between the framework and the existing research and literature can be visible on Figure 3. A more extensive literature review is required to precisely identify the gaps and the innovation potential on the market.

Limitation of the conducted study is primarily a limited number of verification cases, which have been taken from the existing cooperations and known projects. A more extensive verification is required in the future. The scope is focused on the Austrian EoL practices, and needs to be expanded to other countries. Also, the time factor in the EoL processes was not verified, which could affect the proposed framework.

The next step is to perform an extensive literature review in order to identify the gaps in the research of digitalization of EoL, and also to identify the factors for each particular step in the framework which influences the processes during the phase. The results will be used to enhance digitalization and provide tools for more efficient deconstruction. The project tends to facilitate use of Blockchain technology to support the novel improvements.

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Exploring Social Media as Mean to Manage Construction Project Stakeholders

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Abstract:

The construction industry is characterized by highly interdisciplinary, fragmented, and temporary project organizations, process discontinuities, and unique projects. Numerous contracting parties and a vast range of potentially conflicting interests requires strategic and problem-solving approach to stakeholder related issues. Social media platforms provide a new paradigm for communication and can assist in collaboration between project managers and various stakeholders. Recently some researchers addressed usefulness of social media in project management, but little is known of its impact on management of construction stakeholders. Thus, this paper provides a systematic review on social media as tool to manage construction project stakeholders. Results are presented through quantitative and qualitative content analysis of retrieved papers. Some interesting insights are provided. The use of social media related data combined with emerging new analysis methods based on machine learning are driving the development of new research methodologies specific to social media. Furthermore, social media can be used to provide robust analysis of external project stakeholders which can help in devising smart engagement strategies in large construction projects. It is obvious that social media related research field is rapidly developing, and the fact is that stakeholder engagement and communication are reaping the most benefits from social media enhanced project management. Suggestions for further studies are provided for this emerging area of digital project management.

Keywords: *social media; construction; projects; stakeholder; analysis; engagement*

1. Introduction

The construction industry is characterized by highly interdisciplinary, fragmented, and temporary project organizations, process discontinuities, and unique projects (Gustavsson et al., 2012), and this fragmentation is making it very difficult to meet construction project requirements in terms of cost, time, and productivity (Jahanger et al., 2021). The construction industry is also known to be very traditional when it comes to adoption of innovations in processes and organization which is corroborated by the fact that the construction industry is among the least digitized industries (Agarwal et al., 2016). Nevertheless, digitalization is a hot topic in the construction industry today with various relatively mature ICT systems and related researches such as web-based project platforms, digital meetings, and BIM (Damstrom, 2020). One of the issues is that ICT tools are mostly not used to their full potential (Meneiluik and Nikiforov, 2022; Gustavsson et al., 2012) but there are good examples that proper digitalization of construction and project management practices can help in reversing the decline in productivity that construction industry is experiencing (Jahanger et al., 2021).

Through rapid advancements in ICT, opportunities arise in enhancing communication and collaboration between project stakeholders and various organizations involved in construction projects (Adriaanse et al., 2004). Social media has already proved in some cases (e.g. in complex infrastructure project) to be one of the key ICT systems for management of external stakeholders projects (Ninan, Mahalingam, Clegg, et al., 2020) as well as valuable tool to communicate with internal project team members (Prebanic and Vukomanović, 2021). One of the most vocal benefits of using social media in project management is wider coverage and reach of project stakeholders and fast, visible and quick information sharing (Kanagarajoo, 2021) which is both very important in construction projects (Akhwaba, 2021; Wikforss and Löfgren, 2007). One thing that is required for usage of social media is to have access to an internet connection and by having that reach and richness of information exchange can be greatly enhanced i.e. stakeholder information needs can be promptly met and rendered with interactive capability (audio or video) or just pure document format (Kanagarajoo, 2021). Some scholars predict that new digital ways of communication (i.e. social media tools) will transform project stakeholder management, providing both opportunities and challenges (Lobo and Abid, 2020). There are scarce body of literature on social media adoption in construction industry (Ma, Jiang, et al., 2021) and authors are emphasizing the need for further examination of this topic to advance knowledge in this field of digital project management. Thus, this research is intended to fill this gap and explore social media as mean to manage construction project stakeholders and this will be made through systematic literature review methodology.

This article is structured in five sections. First section is the introduction which briefly explain article research subject and it is followed with the brief literature review which explains the core concepts of social media and stakeholder management in construction projects. Third section explains the methodology explaining the path to the final set of articles which are analysed and elaborated in section four. Final section provides discussion and the concluding remarks on social media enabled management of the construction stakeholders.

2. Brief literature review

2.1 Social Media

Social media can be defined as a group of internet-based applications built on foundations of Web 2.0, that allow users to create and exchange user-generated content (Kaplan and Haenlein, 2010). Jackson (2010) elaborates that Web 2.0 comprises a set of knowledge tools that enable knowledge creation, interaction, collaboration, networking and sharing. Kietzman, et al. (2012) proposed an social media functionality model that helps managers and researchers to understand different social media functionalities and this model has the seven constructs:

- identity,
- presence,
- relationships,
- conversations,
- groups,
- reputations
- and sharing

Kietzman, et al. (2012) also emphasizes that building blocks of the model are neither mutually exclusive nor do they all need to be included in a particular social media context. For project management area Troukens (2012) classification with accompanied social media tools is the most pronounced and Kanagarajoo (2021) made some slight alterations providing the adjusted form of this classification (table 1).

Table 1 Social media categories and related tools (adjusted from Troukens (2012) and Kanagarajoo (2021))

Number	**Social media category**	**Social media tool**
1	Microblogging	Twitter, Tumblr, Plazes, Twitpic…
2	Publishing	SharePoint, WordPress, Basecamp…
3	Sharing	YouTube, Dropbox, Slideshare, Flickr…
4	Social Networks	Facebook, LinkedIn, Ning, MySpace…
5	Discuss	Skype, Google Talk, Yahoo Messenger…
6	Event Organiser	EventBrite, Eventful, Doodle, Meetup…
7	Advice	Epinions, yelp!, Customer Lobby…
8	Career	Monster, BCentral, Career Builder…

Kanagarajoo (2021) research generated evidence that the social media categories of sharing, discuss and publishing were most used across all PMBOK knowledge areas and that social media is increasingly being used in projects. Also he emphasized that project teams are benefitting from using social media tools and that benefits can be extended to the organisation as whole. According to Wamba and Carter (2014), the adoption of social media tools for project management depends significantly on the industry sector, the innovativeness of the firm under consideration, its size, and the age of the firm’s management.

2.2 Construction project stakeholders

Large construction projects are mostly focused on overcoming current infrastructure capacity problem (Kumaraswamy et al., 2017) and these projects include numerous contracting parties and a vast range of potentially conflicting interests, which requires problem-solving activities such as stakeholder management (Walker et al., 2008). Classification of construction project stakeholder provided by Winch (2010) categorizes stakeholders into two major groups of internal stakeholders (i.e., contracted parties such as the contractor) and external stakeholders (i.e., indirectly involved such as the affected local community). Figure 1 portrays two-order role-based classification of project stakeholders provided by Winch (2010).

Internal stakeholders		External stakeholders	
Demand side	*Supply side*	*Private*	*Public*
Client	Architects	Local residents	Regulatory agencies
Financiers	Engineers	Local landowners	Local government
Client’s employees	Principal contractors	Environmentalists	National
Client’s customers	Trade contractors	Conservationists	Government
Client’s tenants	Materials suppliers	Archaeologists	
Client’s suppliers		Non-governmental organisations (NGO)	

Figure 1 Stakeholders in construction project (Winch, 2010)

Stakeholder management comprises two major (overarching) processes (e.g., stakeholder analysis and engagement) (Yang et al., 2011), and it is increasingly becoming a part of construction project practice (Bal et al., 2013). Significant empirical research conducted in recent years further divides stakeholder analysis processes (i.e., stakeholder identification, classification, assessment of stakeholder influence, etc.) (Prebanic and Burcar Dunovic, 2017; Yang and Shen, 2015) and stakeholder engagement processes (i.e., stakeholder communication, involvement, collaboration, etc.) (Yang et al., 2011; Chinyio and Akintoye, 2008) which is consistent with stakeholder management becoming a formal project management knowledge area (Project Management Institute, 2013).

2.3 Exploring social media as mean to manage construction project stakeholders

Using digital technology for communication and collaboration is often seen as an important managerial tool, and project managers are left with the increasingly important task of finding proper ways to harness ICT collaboration tools for the involvement of project stakeholders (Chung et al., 2009). Ma et al. (2021) research confirms that social media use has a positive impact on the communication effectiveness of construction project teams and they emphasized that more research should be done in order to get more detail insight in social media tools and strategies for project team collaboration. Kanagarajoo (2021) stated that project communication and stakeholder management were two PM areas most influenced by social media. The goal of this research is to provide more insight in research regarding social media usage for engagement, collaboration, and communication of construction project stakeholders.

3. Methodology

Researchers use systematic literature reviews (SLR) to provide readers with syntheses and analyses of research in specific subject areas (Fink, 2014). The approach is particularly suitable when the analyzed subject is fragmented across fields of study (Denyer et al., 2008). In this study, a selection and analysis of papers is conducted following the established PRISMA statement methodology (Moher et al., 2010), where PRISMA stands for "preferred reporting items for systematic reviews and meta-analyses". The PRISMA statement is a checklist covering all critical issues that should be reported and consists of a flow diagram that presents the research procedure (figure 2).

In stage 1 (identification), we conducted a comprehensive exploratory desktop literature search through two major databases of scientific literature, namely "Web of Science Core Collection" and "Scopus" which are the largest citation and abstract databases in the fields of technology, science, etc. (Alaloul et al., 2021). Computer search was done through keywords for "social media" and "stakeholder management", which was searched in context of "construction projects". Each keyword was supplemented with various expressions used as a proxy, i.e., "construction* project*" was supplemented with "AEC industry*", "construction industry*", "infrastructure mega-project*", etc. Stakeholder management has been categorized and classified into the several processes and practices of stakeholder analysis and stakeholder engagement presented in the previous section, so we used them as a proxy for the stakeholder management discipline. Furthermore, we divided "stakeholder" and "management" (and their proxies) to prevent excluding valuable sources because expressions are often stated in various ways, i.e., "managing project stakeholders". An initial search retrieved 77 items. Filtering was done to exclude duplicate items. Finally, we finished this stage with 51 journal and conference articles, book chapters and other types of literature.

In stage 2, screening was performed on 51 items of literature that were screened by their title, abstract, and keyword list. We screened out items which were not written in English, not journal or conference paper type of literature source and were not remotely associated with the management of construction stakeholder through social media and did not fall into the construction project management context (i.e., articles such as "Quantify the role of superspreaders -opinion leaders- on COVID-19 information propagation in the Chinese Sina-microblog"). This resulted in the exclusion of 15 items, so 36 conference and journal papers remained for stage 3.

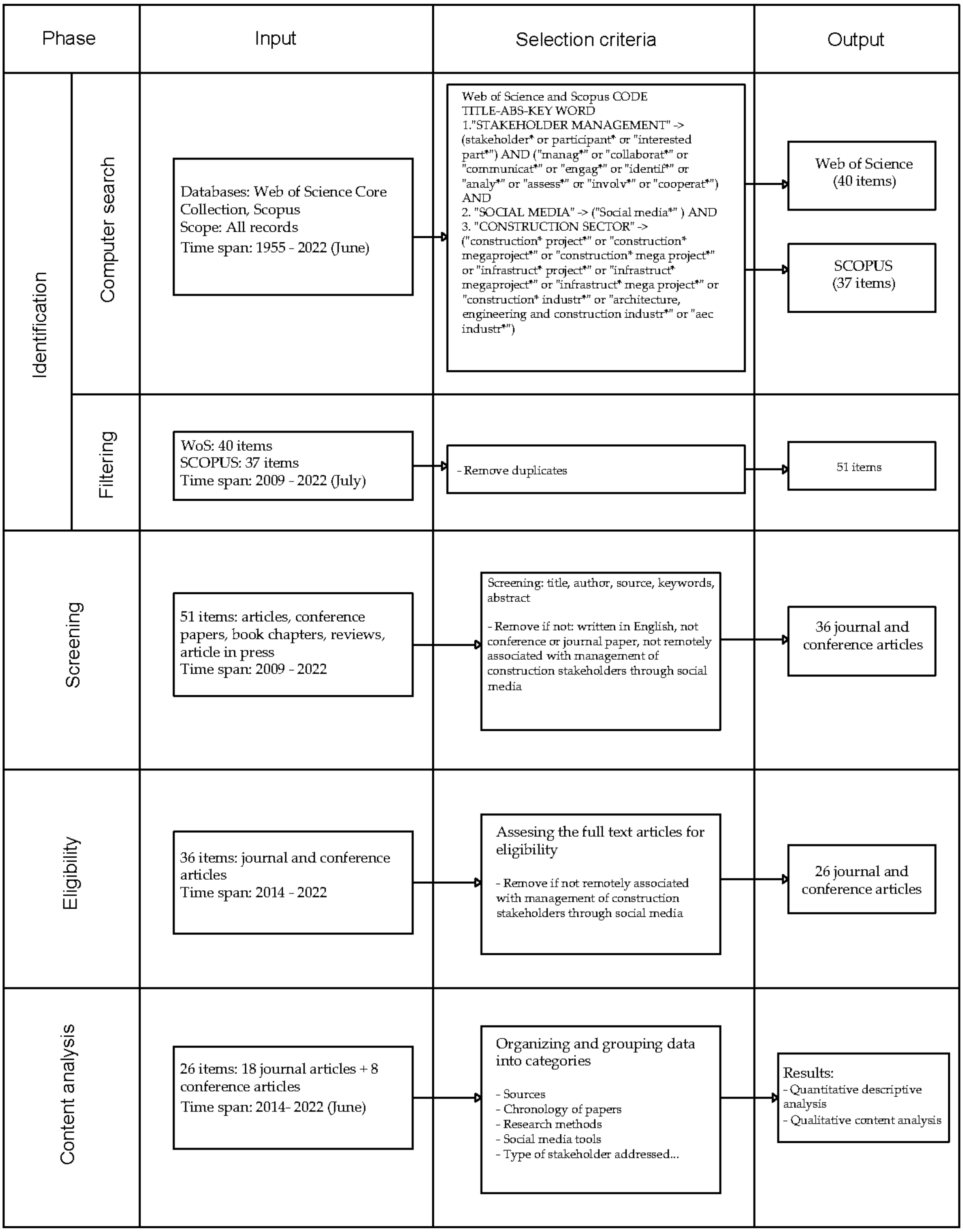

Figure 2 Research methodology

In stage 3, the goal was to check papers for eligibility and retrieve a final set of items which would undergo quantitative and brief qualitative analysis. Articles were visually examined, and each article that did not provide any valuable conclusion on a social media enabled approach to any type of various stakeholder analysis or engagement practices (i.e., articles dealing with "Infomediary Business Models for Connecting Open Data Providers and

Users") or, in other words, that did not explicitly link stakeholder management practices with any form of social media was excluded. The final set of literature consist of 26 sources of literature, 18 journal articles and 8 conference articles.

Finally, in stage 4, the contents eligible journal and conference articles were considered for a content analysis. For this study, content analysis was appropriate because it could be used to determine the major facets of a set of data by counting the number of articles that elaborate a specific process, social media tool, or topic (Fellows and Liu, 2015). Additionally, both qualitative and quantitative analysis methods were employed in this study. For qualitative and quantitative content analysis of the chosen papers, we used the guidelines for code development provided by Seuring and Gold (2012). For content analysis purposes, we iteratively developed precise codes related to our research topic and presented them in a table codebook (Table 2) (Laplume et al., 2008).

Table 2 Codebook for content analysis of this study. Adapted from Laplume et al. (2008)

Code	Definition of Code
Quantitative variables coded	
Authors	List of authors
Article Title	Title of the article
Source Title (Journal and conference)	Publication in which the article was published
Publication Year	Year of publication
Research methodology	Case study, conceptual research, survey, mixed-methods, app development, literature review, other
Social media analysed as data collection tool	Yes or No
Type od data analysis used in social media related data collection	Any type of data analysis method (i.e. topic analysis, social network analysis…)
Stakeholder category	Two major stakeholder categories (internal or external or both)
Social media tool or system	Number of tools (i.e Twitter, Facebook, Sina Weibo…).
Project Phase	Various project phases (conceptualization, design, construction…) or combination or all phases
Qualitative variables coded	
Contributions to research subject	Level 1 – concept enrichment, Level 2 – concept acknowledgement, Level 3 – concept vaguely recognized

4. Results

In this section, we present the results of the content analysis, which was mainly done through, descriptive quantitative analysis. Brief qualitative analysis is also provided at the end of this section. We focused our quantitative descriptive content analysis to categorize final data set based on quantitative codes such as year of publication, the source of publication or social media tool that was addressed in the article etc. Not all retrieved articles can be analysed through each code presented in table 2 and when this occurred label non-aplicable (N/A) was used. Coding scheme was devised following Seuring and Gold (2012) guidelines and the most codes are good fit for the majority of articles.

For the brief qualitative content analysis, we divided articles which explicitly addressed the topic of social media tools usage for construction stakeholder management from other articles which address this subject in more indirect manner. Other part of the retrieved articles addressed management of construction project stakeholders as secondary topic or mentioned it very vaguely in implicit manner.

4.1 Analysis of final data set

In Table 3, the distribution of retrieved literature (e.g. 26 articles) is provided based on publication source title (e.g. in which journal or conference proceeding is article published).

Table 3 Distribution of retrieved literature by publication (source) title

Publication (source) title	Authors	Number of articles
Journal Articles		
Advanced Engineering Informatics	(Corry et al., 2014)	1
Automation In Construction	(Nik-Bakht and El-Diraby, 2017)	1
Buildings	(Ojelabi et al., 2018)	1
Civil Engineering Journal-Tehran	(Al-Shehan and Assbeihat, 2021)	1
Computer-Aided Civil and Infrastructure Engineering	(Nik-Bakht and El-Diraby, 2016)	1
Construction Management and Economics	(Ninan, Mahalingam, Clegg, et al., 2020)	1
Engineering Construction and Architectural Management	(Ma, Jiang, et al., 2021)	1
Engineering Project Organization Journal	(Ninan, Mahalingam and Clegg, 2020)	1
International Journal of Human-Computer Studies	(Nik-Bakht and El-Diraby, 2015)	1
International Journal of Project Management	(Ninan et al., 2019)	1
International Journal of Sport Communication	(McGehee et al., 2018)	1
Journal Of Construction Engineering and Management	(Ma, Jia, et al., 2021)	1
Journal Of Infrastructure Systems	(Nik-Bakht and El-Diraby, 2019)	1
Project Management Journal	(Lobo and Abid, 2020) and (Williams et al., 2015)	2
Sustainability	(Prebanic and Vukomanović, 2021)	1
Transportation Research Record	(Minooei et al., 2018)	1
Water Policy	(Zhang et al., 2018)	1
Conference articles (proceedings)		
2015 IEEE International Professional Communication Conference (IPCC)	(Digmayer et al., 2015)	1
Computing in civil engineering 2017: information modelling and data analytics	(Tang et al., 2017)	1
Construction Research Congress 2018: Construction Information Technology	(Tang et al., 2018)	1
Construction Research Congress 2018: Sustainable Design and Construction And Education	(Paige and Thirukkumaran, 2018)	1
Construction Research Congress 2020: Computer Applications	(Ahmed et al., 2020)	1
ICSDEC 2016 - Integrating Data Science, Construction and Sustainability	(Grovera and Froesea, 2016)	1
International Conference on Smart Infrastructure and Construction 2019, ICSIC 2019: Driving Data-Informed Decision-Making	(Li et al., 2019)	1
Proceedings of the 21st European Conference On Knowledge Management (ECKM 2020)	(Ulhaq et al., 2020)	1

There is no single prevailing journal for the observed research area, moreover only one journal (e.g. Project Management Journal) has more than one publication regarding the topic of social media enabled management of construction stakeholders. Publications are scattered in 17 different journals and 8 different conference proceedings, although Construction

Research Congress series of conferences contains three articles. Based on this result it can be concluded that this topic is scattered along the multiple different sources of literature (e.g. journals) covering broad research area but the majority of this sources are from construction and civil engineering field.

Based on the year-wise distribution of the selected articles (Figure 3) it is evident that this is very young and emerging research topic. First article related to this topic is published in 2014. and more than two third of articles are published from 2018 and 2022. It is apparent that social media is one of the latest ICT systems being researched as a tool to manage project stakeholders and this is in line with assertion that social media is rapidly developing as a business and (project) management tool.

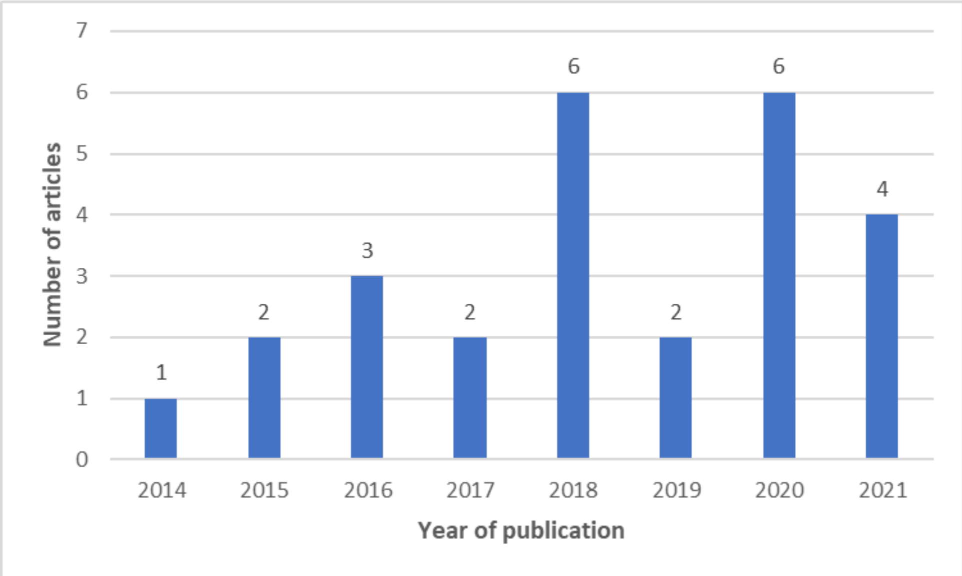

Figure 3 Year-wise distribution of the selected articles

To explore the nature of the research topic it is very useful to observe what research methodologies are used (Figure 4). We detected only four different research methodologies namely, survey, systematic literature review, analysis of social media posts and case study. It is very interesting that apparently new research methodology emerged which is specifically linked to this specific type of ICT system (e.g. social media) and it is based on data collection (i.e. key words) done in search engines of one of the social networks (i.e. Twitter). Whole methodology is based on research topic which data collection and analysis methods are being researched in the realm of social media posts and comments. Other interesting result is that large number of articles employs case study methodology (or something very similar). Giving the fact that this is emergent field of study it is logical to explore it in depth and advance its theoretical basis which is best done through case study. Some articles explored new types of social media tools or interaction between social media and other ICT tool in form of experimental game, but their approach was alike single case study, so their methodology was labeled as case study.

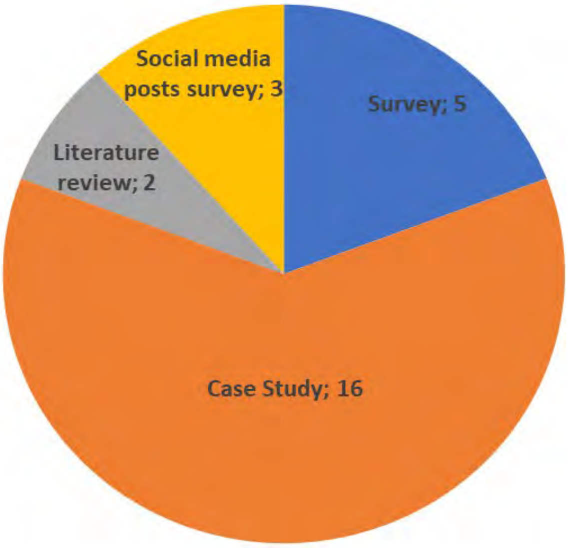

Figure 4 Distribution of articles' research methodology

Regarding the research methodology we wanted to explore the number of articles using social media posts as data pool because this is further evidence that new research methods (i.e. data collection methods) are emerging with this type of ICT system. More than two third of retrieved articles used social media posts and/or comments on posts as the source of the data which are afterwards analyzed (Figure 5).

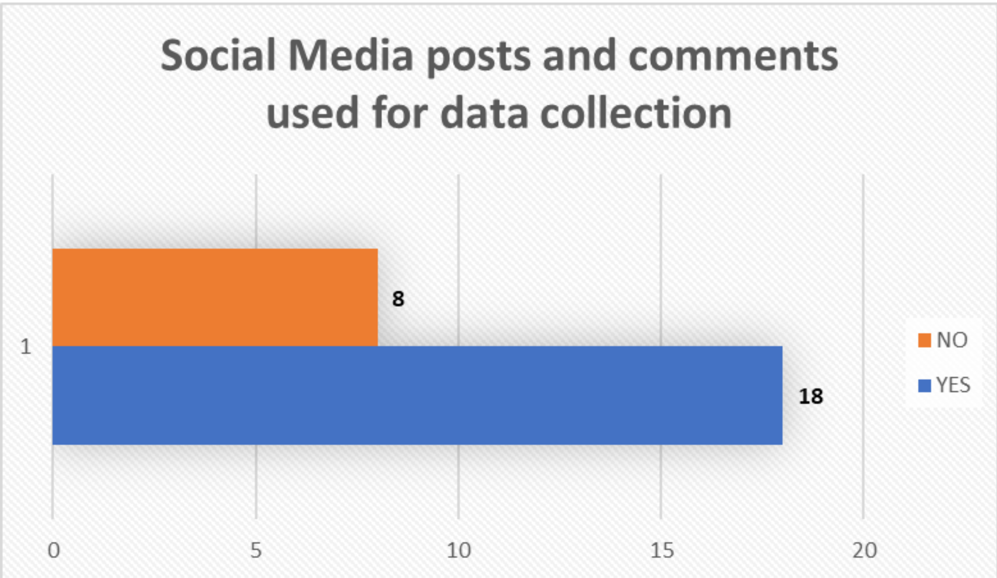

Figure 5 The portion of data collection methods linked with social media posts

For these 18 articles which used social media posts and comments for data collection we explored the nature of data analysis (Figure 6).

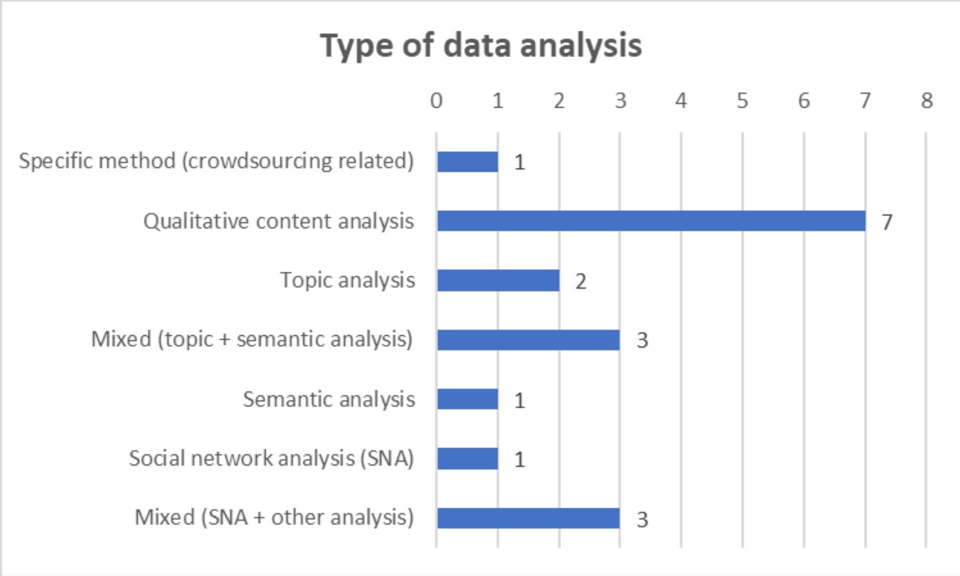

Figure 6 Type of data analysis method used for data which was retrieved from social media posts and comments

In figure 6 several categories were provided which covered various data analysis methods and specific type of mixed data analysis method which were observed in these 18 articles. Qualitative content analysis is still well represented among data analysis methods (e.g. 7 of 18 articles) but various types of ICT boosted analysis methods are slowly taking over as the dominant data analysis methods. Semantic analysis, topic analysis and social network analysis are three methods which are becoming relatively common way of analyzing data polled from social media posts and comments each having its distinct value. Semantic analysis provides the insight of the stakeholder attitude towards the project, topic analysis points out to dominant project related issues raised by project community active on social media and social network analysis provide insight in what are the key stakeholders and key connections which can influence the project.

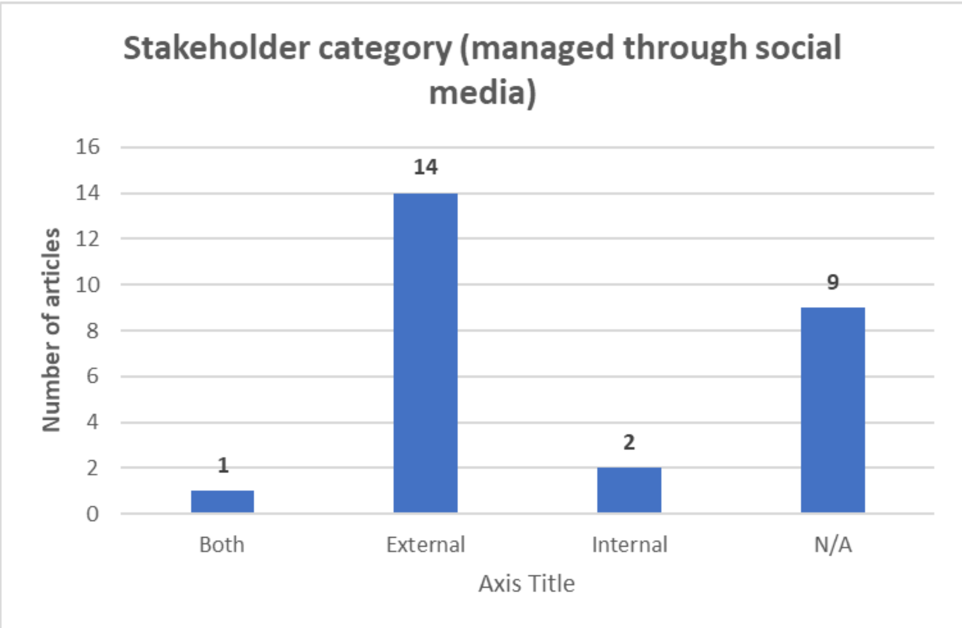

Figure 7 Stakeholder groups that were addressed

As this research is about management of construction project stakeholders, we wanted to see which of the two major distinct categories of project stakeholders are managed through social media (Figure 7). For some articles there is no way of telling which stakeholder groups are addressed because it is not specified (i.e. only term stakeholder is used) but in the majority of articles it has been addressed at least what major group is analyzed. In most cases social media was used to manage external stakeholders (based on previously shown Winch (2010) classification) whether it was about building end users, local community, or public community stakeholders. Very small number of articles addressed social media as mean to manage internal project team and only one article clearly addressed social media as tool to manage both major groups of construction project stakeholders.

Another code which was explored is the exact social media tool which was analyzed in articles (Figure 8). As it was earlier shown many of the articles used case study methodology and these articles usually stipulate which social media tool (system, platform) is observed. Also, some other types of articles (i.e survey or social media survey) addressed which social media tool is observed and for other articles label N/A is used. It is apparent that microblogging social media tools are the most often subject of research because platform like Twitter and Sina Weibo are present in more than half retrieved articles. Sina Weibo is the most popular Chinese microblogging platform. In addition to these platforms only Facebook is mentioned relatively frequently as a part of the research. Other types of social media platforms are very rarely researched as a tool for construction stakeholder management.

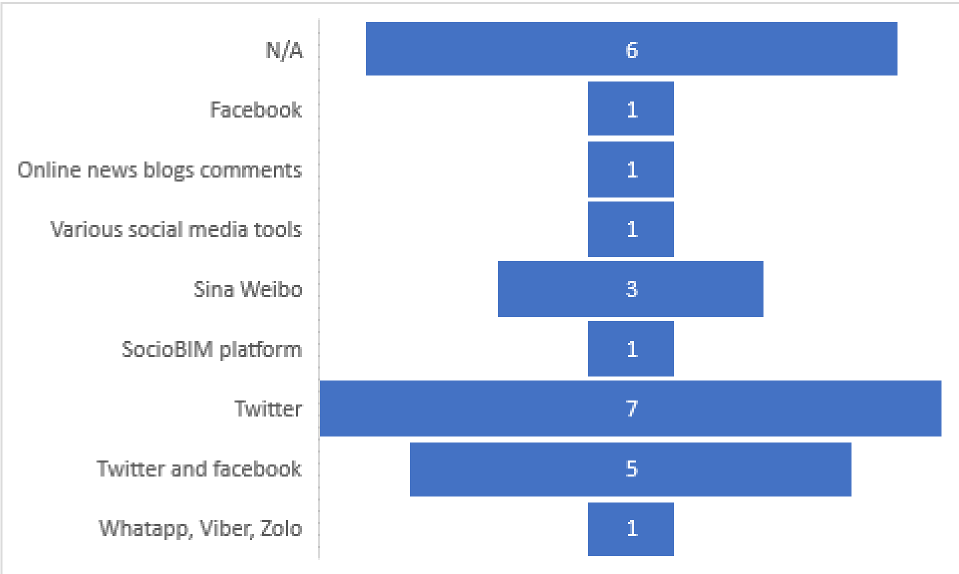

Figure 8 Social media tool or system analyzed

Important part of construction stakeholder management is the phase in which stakeholders are engaged and thus we explored project phases which were observed in articles (Figure 9). Again, there are relatively large portion of articles which did not stipulated any project phase (i.e survey questionnaire types of articles) but in more than a half articles scholars clearly observed social media stakeholder management in particular project phase(es). Four articles observed social media interactions throughout the whole project (analysis in several points in time or post project analysis) and four articles were multiple case studies so social media usage was observed in various phases depending on the case observed.

In several articles management of stakeholders through social media was observed in only one or two project phases.

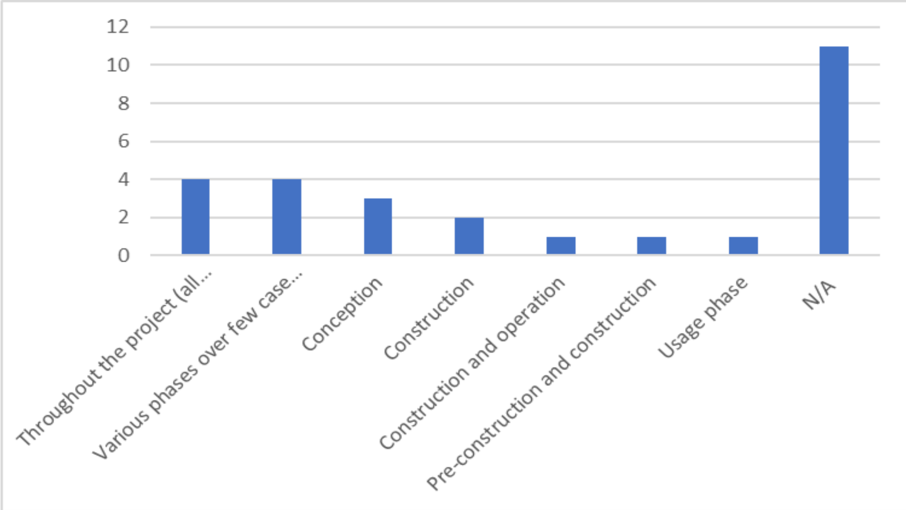

Figure 9 Project phase in which social media usage was observed

The last code analyzed was the depth in which articles elaborated our research subject. We divided articles in three categories, articles which explicitly analyzed topic of how to use social media to perform some processes and/or activities related to analysis or engagement of project stakeholders and they very precisely explored this topic. We labeled them as level 1 - concept enrichment based on classification provided by Littau et al (2010) which we slightly adjusted and this level 1 mean that the topic is explored in depth and that it provides new insights (i.e new method to analyze project stakeholder and determine their potential influence).

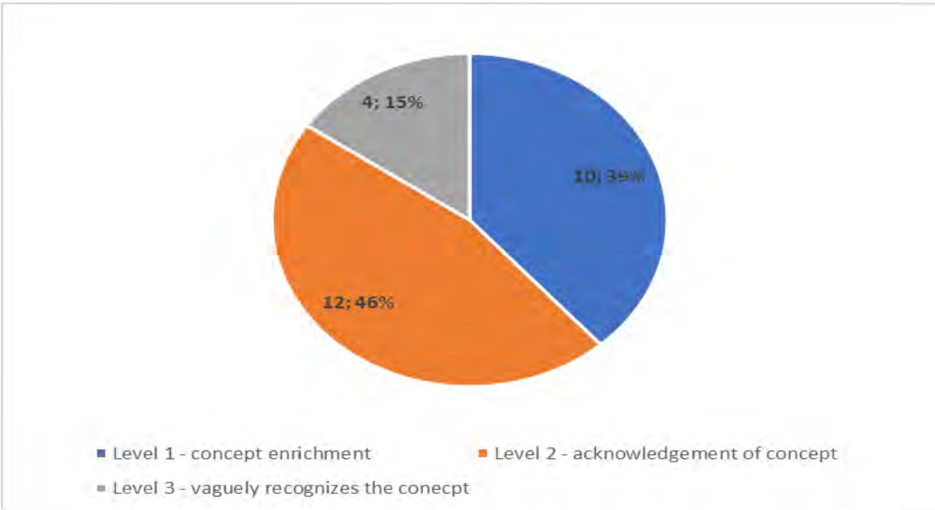

Figure 10 Breadth of contribution for subject of "management of construction stakeholders through social media"

Other category consists of articles which explored social media in relation to (project) management in which stakeholder management was secondary or one of the many topics addressed and we label this level 2 – concept acknowledgement because they clearly acknowledge that social media can be used to manage construction project stakeholders. The last category was articles which addressed social media and stakeholder management almost completely independently, but they did vaguely relate these two concepts.

5. Discussion and conclusion

Subject of this article was to explore social media as mean to manage construction project stakeholders and it was made through systematic literature review methodology. Following PRISMA methodology final set of 26 journal and coference articles was retrieved. These articles were analyzed through codes which were carefully developed following guidelines from Seuring and Gold (2012).

The most important insights will be emphasized. First it is evident that this topic is only emerging with all articles published in the last eight years (first was in 2014.) and more than two third in the last four years. Second it is apparent that these new types of social media tools and systems drive the development of new methodologies for data collection and data analysis. These methodologies are based on mining the data from social media posts and comments and analysing them with the help of machine learning and artificial intelligence data analysis methods. Third it is obvious that the most pronounced nature of social media enhanced stakeholder management is the management of the external stakeholders, mainly building end users and local community. Fourth only one part of the research articles drives the development of this field by explicitly studying the management of construction project stakeholder through various social media tools and platform. These articles mainly implement case study methodology to explore about how social media can be used for managing stakeholders. This approach often brings new insights or develops new methods of stakeholder analysis or engagement. This is very important because there were concerns about stakeholder analysis being prone to cognitive limitation of project management team which performs the analysis. This can now be transcended with rapidly developing machine learning and artificial intelligence analysis of stakeholder social media posts and comments which are being explored in these recent articles. Other part of the reviewed articles acknowledges the concept of managing stakeholders through social media, but they are mainly exploring the rate of the adoption of social media. These articles also provide some new insights.

Results of provided analysis leads to conclusion that social media is becoming increasingly important tool to manage construction project stakeholders mainly because social media is virtually free and relatively simple to use compared to other similar methods for sharing important project related information (i.e. audio, video or any other type of media). Main limitation of this research is that analysis is mostly quantitative and descriptive in nature so there is space for more qualitative insight in how to manage stakeholders through social media. There is a vast opportunity of research in this field and undoubtedly stakeholder management research area will benefit from development of social media and similar digital platforms and tools.

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ICT Tools in Project Management - A Case Study from the Practice of PDM Savjetovanje d.o.o.

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Abstract:

The paper gives a brief overview of the ICT software tools applied in the context of effective project management in a company whose primary activity is construction project management and construction supervision. The emphasis is on the use of software for planning and evaluation of the dynamics and costs of projects (*Microsoft Project and Primavera P6*), for monitoring the quality of work (*PlanRadar*), for communication (*Outlook Shared Mailbox, Microsoft Teams*), for document management (*Microsoft SharePoint*), and on the use of custom models developed in the framework of *Microsoft 365* and *Microsoft SharePoint* for the project management and the reporting of the project status to the customer. Investing in ICT, educating employees and focusing on innovative solutions is a continuous task of the company's management. Such an approach, in addition to the added value for public investors on the projects it works on, ensures that PDM Savjetovanje d.o.o. is recognised by private investors as a valued partner in the management of significant projects.

Keywords: *project management; virtual team communication; project websites*

1. Introduction

The project-oriented nature of the construction sector is its specific feature compared to the rest of the production sector. IPMA defines a project as "unique, temporary, multidisciplinary and organised endeavour to realise agreed deliverables within predefined requirements and constraints" (IPMA, 2018). Furthermore, it reads: "Project management is concerned with the application of methods, tools, techniques and competences to a project to achieve goals." (IPMA, 2018).

On each new project, different stakeholders meet with their own interests, experiential knowledge and other expertise. Figure 1 shows the key stakeholders during the life cycle of a construction project.

Successful project implementation implies the satisfaction of various expectations of stakeholders, whether in terms of price, quality and deadline, or the satisfaction of the end user, the lifetime performance of the product and its sustainability. In achieving these objectives, information and communication technologies (ICT), based on intensive knowledge and modelling, enable stakeholders to get a holistic support and make the right decisions in the implementation of the project (Buć and Divjak, 2008).

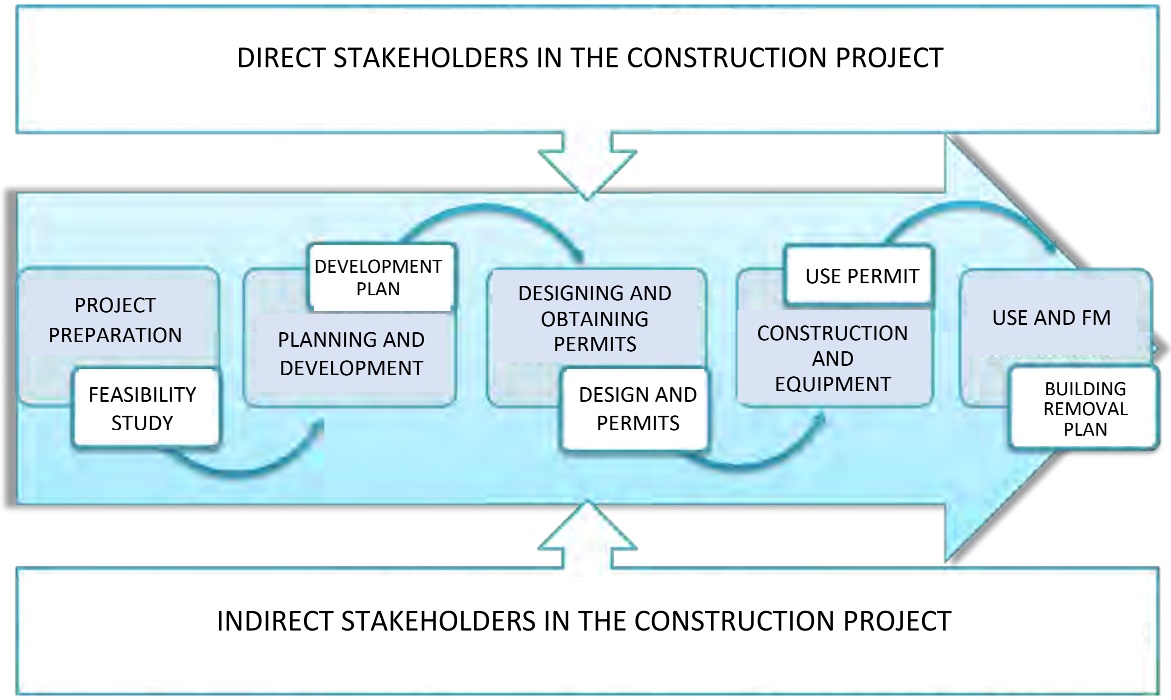

Figure 1. Key stakeholders during the lifetime of a construction project (Buć, 2018)

Information and communication technologies (ICT) consist of hardware, software, networks and media for the acquisition, storage, processing, transmission and presentation of information (voice, data, text and image), as well as related services.

Froese (2010) classified the use of ICT in construction projects into three basic phases, from the oldest to the newest, each of which is still evolving. The first phase refers to the development of stand-alone software for the support of other activities, such as *Computer-Aided Design* (CAD), budget construction, planning, etc. The second phase of the ICT implementation is focused on computer-assisted communication: *e-mail*, the Internet, document management systems, etc. The third phase is the application of innovative ICT solutions for the integration of their processes into the life cycle of the building, through *Building Information Modelling* (BIM), virtual design and construction.

In recent years, the scientific and engineering literature has been increasingly talking about Construction 4.0, the fourth industrial revolution that will manifest itself in construction from automated production to a higher level of digitisation through BIM, cloud computing technology, IoT (Internet of Things), Big Data technology, as well as the use of robots, unmanned aerial vehicles (drones), laser scanners, and radio frequency identification (RFID) readers, etc. (Craveiro *et al*., 2019). Meanwhile, the process should not be too fast nor slow, with regard to the low level of innovation and the structure of the construction industry - predominantly small and medium-sized enterprises with a very different technological maturity (Klinc and Turk, 2019).

In Croatian construction sector, the level of digitisation, viewed through the prism of the level of BIM application in domestic construction, is substantially low compared to European and global markets (Kolarić *et al* , 2020). As most of the projects in Croatian construction are implemented without BIM, it is necessary to make use of the opportunities offered by the current development of ICT to improve the cooperation of stakeholders in construction projects.

In the construction project management business, the following main challenges for applying ICT to improve the project management output can be identified:

- communication between remote team members
- project documentation management
- planning and monitoring of project implementation
- reporting.

There is a whole range of project management software on the market, such as (Kashyap, 2022): ProofHub, Scoro, Workzone, Proprofs, Zoho Projects, Easy Project, etc. In addition to the above, Microsoft Project, Oracle Primavera P6, Open Plan Professional (OPP), FastTrack Schedule, and much other software, packages, and platforms are most often used for planning (Sepasgozar et *al.,* 2019).

This paper gives a brief overview of the ICT applications in the above-mentioned challenges to the successful management of construction projects, which are applied by PDM Savjetovanje d.o.o. from Zagreb in its project management methodology.

First, it gives basic information about the product, followed by an overview of the applied tools and in-house solutions.

2. PDM Savjetovanje d.o.o. for consulting and services

PDM Savjetovanje d.o.o., Zagreb, is a private company. The company is managed by directors Željko Štromar and Neven Martinec, who are also co-owners. The company has ten permanent employees, and, on average, the same number of close associates in teams working on various projects.

The company is, in particular, registered for business and management consulting and construction project management. The company provides its services primarily to private investors, or manages EU-funded projects. The company provides project management and construction supervision services for the construction and reconstruction of hotels and hospitality facilities, office buildings, hospitals, shopping and logistics centres, large buildings, industrial and infrastructure buildings, as well as project documentation services for ESI-funded projects in the fields of infrastructure, environment and energy efficiency. In addition, due to the specialist knowledge it possesses, the company also participates in technical processes of in-depth analysis and reviews of project documentation, as well as in specialised parts of projects aimed at reducing energy consumption, CO_2 emissions and noise protection.

The company operates in a large part of the Republic of Croatia, which requires high mobility of employees, ICT equipment and adaptability to different working conditions. The employees of PDM Savjetovanje d.o.o. are highly motivated and open to the application of new knowledge and innovative technologies. We can work on projects that are implemented in BIM, but we also use various software for budget and cost calculations, software for planning and work (*Microsoft Project and Primavera P6*), as well as for the identification of defects and the dynamics of their resolution during the project (*PlanRadar* application), software for calculating the acoustic performance of a building (*The Predictor-LimA; BASTIAN*), the *IDA/ICE* building energy efficiency stimulation software and the *Microsoft 365* suite.

All employees of the company are certified civil engineers, except for the youngest member of the team, who is in the process of obtaining certification. All employees are continuously pursuing further education in the field of project management in line with international standards. Currently, one member of the team is an *International Project Management Association* (IPMA) A-level certified portfolio manager, five are B-level certified, and one is an IPMA C-level certified project manager. In addition, one of our employees is currently in the process of obtaining the IPMA B-level Project Manager Certificate.

The continuous focus of PDM Savjetovanja d.o.o. on increasing competitiveness is based on the quality of services offered in line with competitors, based on extensive experience, innovative approaches and the use of information and communication technologies, which will be described in a short summary below.

3. Communication of virtual teams

Private investors are aware of the importance of early involvement of an expert in project management, especially at the stage of project preparation, planning and development, which significantly increases the effectiveness of the project's outcome. The first step for effective project management is to establish open and secure communication between the members of the project team (designer, consultant, expert, project manager and his team, and the investor).

Effective project communication is not done spontaneously, it is planned and carried out in a controlled manner throughout all phases of the project. Whether verbal or written, formal or informal, communication is always two-way: one side gives and the other receives information. For information to be useful to the recipient, it must be relevant, timely and accurate. Successful communication management requires that key issues are identified at the earliest stages of a project:

- Whom and what information is needed?
- Who has the necessary information?
- Who is responsible for providing/receiving information?
- What are the best communication channels?

From the earliest stages of a construction project, virtual teams, e.g. designers, consultants, various experts, etc., work in their own arrangements in different cities, even on different continents. This is why linking them together and creating a successful cooperation is often the real challenge (IPMA, 2018). To increase and improve communication on the project, PDM Savjetovanje uses the following ICT tools:

- A shared e-mail address of the project
- Video conferencing
- *Microsoft SharePoint* project site.

3.1. Project's e-mail

Today's communication, both private and business, is almost impossible to imagine without *e-mail*. Simple and effective communication via *e-mail* is our daily routine. Meanwhile, when an individual works in a large project team, or even simultaneously on different projects, his e-mail inbox can be clogged up and unchecked. For this reason, opening and working with a shared mailbox, as a place where multiple users can read and send *e-mails*, has proven to be very practical and useful.

In complex projects, for members of the project management team, PDM Savjetovanje uses *Outlook Shared Mailbox* as an effective basic mailbox for team members who already use *Microsoft Outlook*. We set up a shared *e-mail* address for the project: *nazivprojekta@pdms*. The e-mail sent to this address is visible to all the team members, but answered by the team member who is responsible for it. His reply is also visible to the rest of the team. If consultation is needed before a reply is sent, it is not necessary to forward the *e-mail* received, which reduces the number of e-mails and unnecessarily consumes digital memory. Besides, all members of the project management team are aware of the status and problems of the project, thus avoiding the possibility that someone who should be aware of the problem may not have received information about it (e.g. his *e-mail* address is not forwarded to by mistake, etc.)

3.2. Video conferencing

Meetings - weekly virtual team coordination meetings, monthly meetings to discuss project progress or meetings with investors, various presentations, and even meetings with remote users, all of which are easily held on Microsoft's platform for business communication, *Microsoft Teams* (although there is other similar software, such as *Zoom* or *Google Meet*). During the COVID-19 pandemic, virtual meetings have become the new normal. Microsoft announced in July 2021 that *Teams* had monthly traffic of around 250 million active users (Tejaswi, 2021), but by January 2022 that number had grown to more than 270 million users (Foley, 2022).

Working in *Microsoft Teams* is a very straightforward process - meetings can be scheduled or created *ad hoc* via *Microsoft Outlook* . With the prior consent of the meeting's participants, the meetings are recorded, which allows for their later review and informing the participants who failed to attend the meeting at the scheduled time, as well as the compilation of minutes - the meeting's conclusions with far fewer disagreements about what has been said and concluded at the meeting so far.

3.3. Project websites

PDM Savjetovanje successfully uses the *Microsoft SharePoint* tool for effective business communication and document management with project teams. This application allows the creation of project websites, or team pages of completed projects, as a unique website for the management of tasks and their assignment to team members, for the storage and management of project-related documentation, and for the management of the project team's tasks in a share calendar (Microsoft, 2022).

The most significant advantages of *SharePoint* include high security and compliance, a streamlined information flow and cloud storage which can be accessed via mobile devices. We take responsibility for storage costs and licensing, while external users do not incur any costs when using and operating the system.

Security is the main concern for modern business today. By using *SharePoint* and *OneDrive 365* in projects, we have solved some security issues. We have defined security rules at the company and project level (who can share documents, with whom, when and who must receive information if there is an unwanted information leak). We have implemented all the recommended safety features that we use in compliance with the latest safety standards. We use mandatory MFA (*multifactor authentication*) for all users accessing from outside the company network (from the Internet, another domain or an unfamiliar computer), especially for external users. In addition, we have introduced blocking access to our data from older applications that do not allow modern authentication (e.g. Office 2010).

An example of a fictitious project page is shown in Figure 2 (due to contractual obligations of data protection and confidentiality, we are not allowed to show actual pages of actual projects).

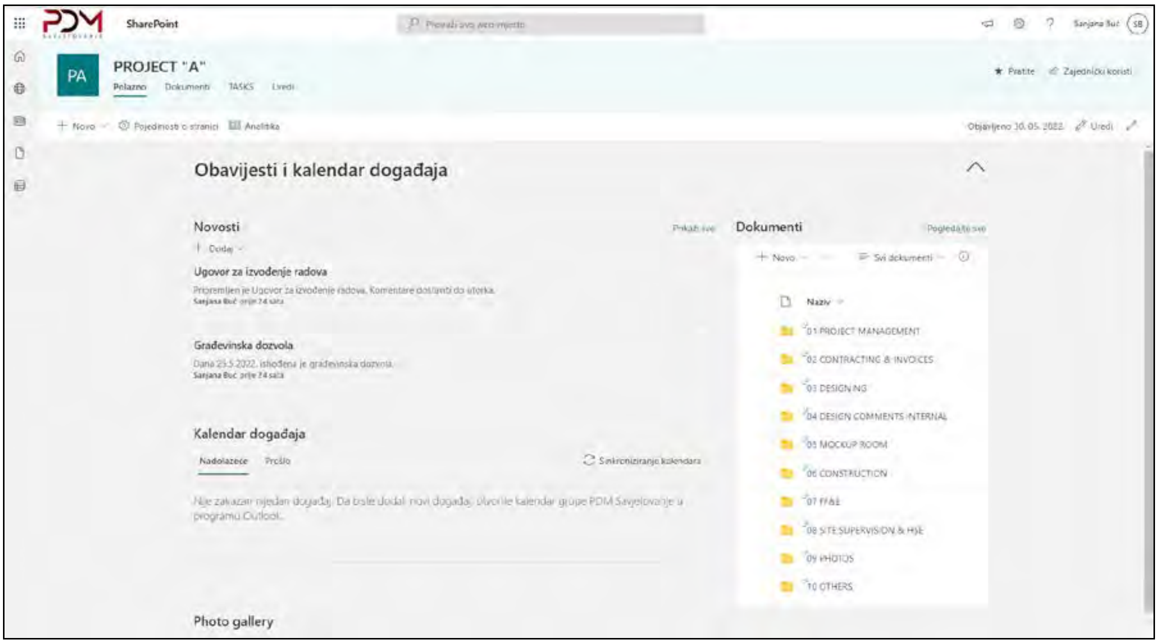

Figure 2. Example of a project website

The assignment and monitoring of the task completion progress is also shown by a fictitious example in Figure 3:

Figure 3. Assigning and monitoring the progress of tasks

Similarly to the Tasks list, the Contact list is also created, displaying the contact details of all project members.

4. Project documentation management

Each *SharePoint* project page has its own name (usually abbreviated project name) and URL (access address). Secure access to individual contents is managed through *Microsoft SharePoint* by assigning an individual user to one of three levels: (1) *Owners*, who are authorised to change the appearance of the page or create new pages, (2) *Members*, who have permission to open, view or add new documents, and (3) *Visitors*, who have permission only to view documents. When editing a document on *SharePoint*, the changes that have been made to the document over time are always visible, so a document, or a part of it, that has been accidentally deleted is not permanently lost.

Figure 4: An example of the hierarchical structure of documents on the project website

For an efficient, quick and easy access to the documents, PDM Savjetovanje has developed a unique hierarchical file structure for its projects (Figure 4 shows the structure only for the first two *Project Management* levels). This allows easily navigating and using individual content not only for an individual member of the project team who has access to documents on that project, but also for an employee who has access to several project websites.

5. Planning and monitoring of project implementation

One of the earliest activities in the project management service is the development of a project management plan. In this plan, PDM Savjetovanje, as a provider of project management services, elaborates the following elements in detail:

- Management of *stakeholders* and communication
- Organisation and responsibility of the PM team
- Decision management
- Risk Management
- Project quality management
- Time planning and monitoring
- Cost and financial management
- Change management
- Reporting.

We use various ICT tools and licensed software in planning and monitoring the implementation of the project management plan.

For example, for the purposes of risk management in a specific project, we create, already at the earliest stage of the project, a risk register in the form of an Excel model - a table resulting from a number of interconnected pages (which define the hierarchical structure of the risk origin) R *isk Breakdown Structure* , RBS), project objectives, risk event probability and impact levels, risk strategies, risk status and risk matrix. In the risk register, possible risk events are monitored for each phase of the Project's implementation. Each risk event is associated with the probability of its occurrence and the severity of the consequences of the risk event for each key Project management criterion (goal) to define the level of risk. Each risk event is accompanied by a brief description of the planned response to the risk and the person responsible for its implementation. The risk register is updated (using the risk matrix) on a monthly basis. The result is also displayed graphically, with a risk label ("Rnumber") in the risk matrix and a polar (radar or spider) graph of the threat to the project's goals (Figure 6).

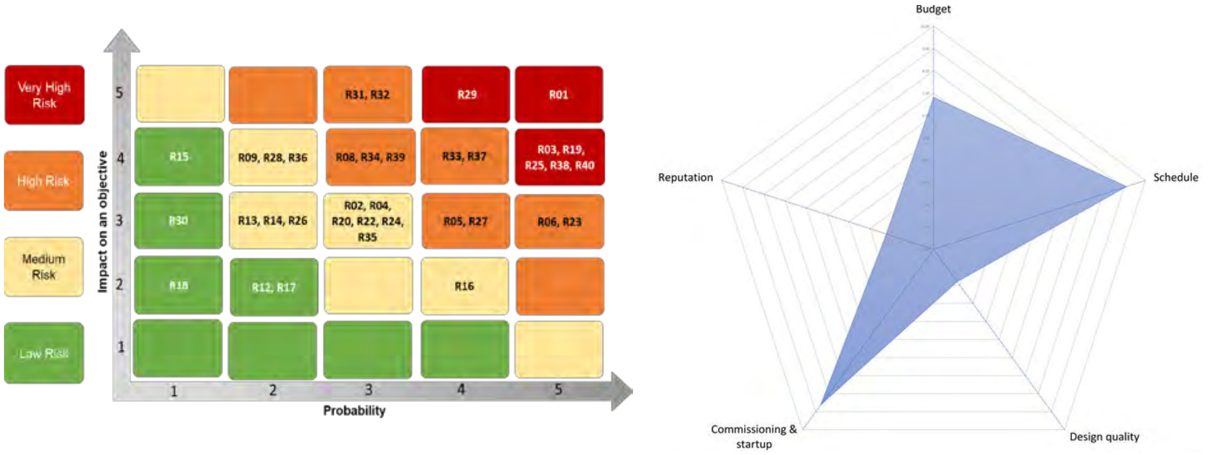

Figure 6: Example of a graphic presentation of project risks and their impact on individual project goals

Managing the quality of a project involves all phases and phases of the project, through the project processes, project team management, deliveries and project closure. Project quality validation is carried out through procedures such as quality assurance (QA), quality control (QC), and project and product audits. To monitor all construction works, identify all shortcomings and the dynamics of their resolving, we also use the PlanRadar application. The above application is used by supervising engineers and contractors as administrators, also the investors and PM team and planners mainly use PlanRadar's web browser version (https://www.planradar.com/).

In particular, the implementation plans according to which the works are carried out are uploaded to the Cloud and are available to all participants (on a tablet or mobile phone). The supervising engineer records the progress of the work, the deficiency records and the deficiency elimination records daily or weekly as shown in Figure 7. During the tour, the supervising engineer detects the deficiency - by putting a red balloon on the blueprint, photographs that deficiency and writes an accompanying comment. The contractor uses the same application to receive an order, solve the problem in question, change the status of the "balloon" to gray. On the next visit, the Supervising Engineer confirms the solution by changing the status of the "balloon" to green or rejects the solution of the problem by changing the status of the "balloon" to black.

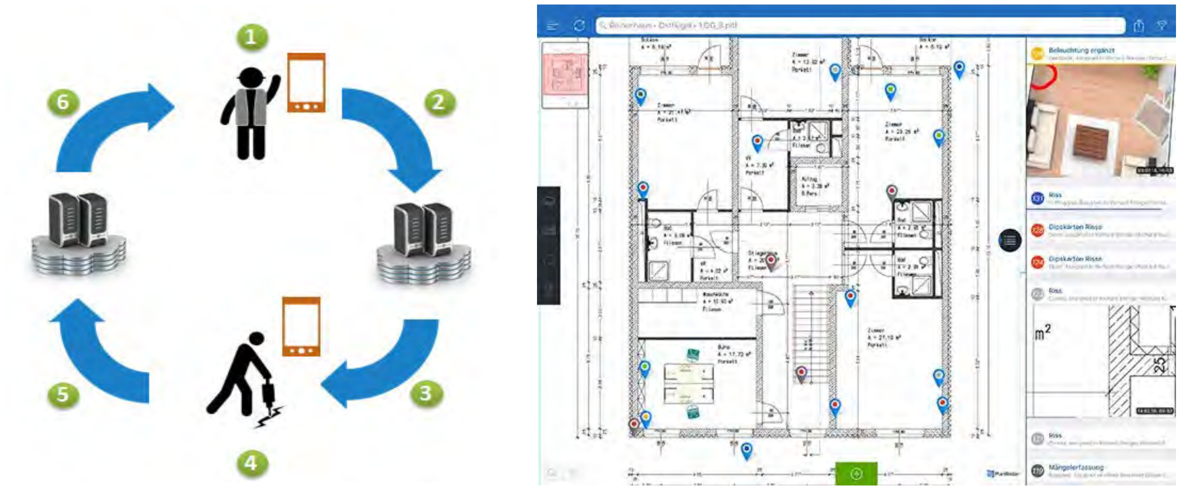

Figure 7: PlanRadar application (PlanRadar, 2022)

The aim of time planning is to determine which activities should be carried out and when, and to place these activities in a logical sequence on a timeline, creating a critical path diagram. When the plan is approved, it becomes the baseline for monitoring . Every further key change in relation to that plan requires the initiation of a change management process and the creation of appropriate revisions of that plan to meet the set deadlines (European Commission, 2018). We use *Microsoft Project* and *Primavera P6* software to plan and monitor deadline schedules.

Project cost and financial management is a combination of all actions necessary to plan, monitor and control costs during the project, including project budgeting and cost estimates in the early stages of the project. Financial monitoring ensures continuous monitoring of the fulfilment of the contract according to the items in the project budget, for each individual contractor and service provider. We use our own models created in Excel to prepare and monitor financial outcome. An example of a graphic representation of the financial outcome in relation to the plan ("S" curve) is shown in Figure 8.

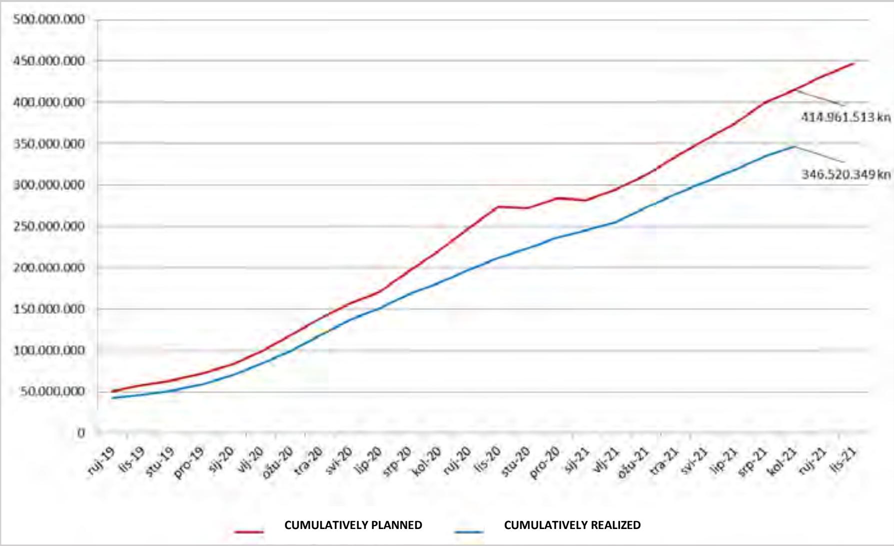

Figure 8: S curve of financial outcome, example

6. Reporting

Regular reporting to the investor, that is, to the customer of the project management service, is essential for timely decision-making related to the implementation of the project. The method of reporting depends, foremost, on whether it is a private or public investor, or whether it is a project financed by EU funds, various financial institutions that have their own reporting policies. For the public client of project management services whose project is co-financed by EU funds, for example, monthly and quarterly reports, as well as the final report, are made, all in accordance with the requirements of PT1, PT2, EK, and the requirements and methodology from the grant agreement.

Unlike the project progress report, an artefact created by the project manager to inform the project management (investment) committee about how the project is progressing compared to the plan, which contains information about the status of project deliverables, risks, major issues, activities, etc., the project status report is delivered much more frequently (e.g. every month) and only contains a one-page summary of project status. This is the most common way of reporting for private investors (European Commission, 2018).

The company PDM Savjetovanje has developed its own model for creating reports on project status. The model was created in *Excel*, and consists of interconnected sheets from which key information is transferred to the main (only) page of the report (*dashboard).* The model consists of: budget, financial monitoring of costs according to concluded contracts in relation to planned costs, time monitoring in relation to the plan for the current period (excerpt from *Primavera*'s time monitoring of the baseline), risk register, main tasks (performance in the past reporting period and plan for the next month), "*red flag*" information, that is, information about critical problems and opportunities. The project status report contains graphical presentations, tables and projections which are the result of the above-mentioned key elements of the reporting model.

7. Conclusion

The management and staff of PDM Savjetovanje d.o.o. have a high awareness of the need to introduce innovative technologies and ICT solutions to continuously improve the quality of project management services. Unfortunately, as the advantages of BIM are not applicable, due to the low level of use of BIM on projects in the Republic of Croatia, the company has not had the opportunity to participate in a project that could be said to implement BIM correctly.

However, the main contribution of this paper is the demonstration of ICT tools for successful management of construction projects - for communication of virtual teams, management of project documentation, planning and execution of project implementation, and evaluation, the quality of which is proven in practice.

The advantage in the selection of software solutions that the project benefits from (*Microsoft Project, Primavera P6, PlanRadar, Microsoft Teams*) in relation to other software and tools available on the market is, primarily, in the interoperability of the ICT systems of the main stakeholders in the project (customer, contractor, supervision, project management). In addition, these tools are not limited only to a single use in a particular segment of the project management work, but they can also be used for other purposes, e.g. time planning and management, or planning and management of other resources: money, people and teams, material and so on (*Microsoft Project, Primavera P6*). Furthermore, *Microsoft Teams* is a platform for business communication that offers a workspace for chat and videoconferencing, or for file storage and application integration. One of the key problems of sharing information and documents in virtual teams on projects is the security of the information system and data protection, which is successfully addressed by *SharePoint* and *OneDrive 365* systems. A further advantage of using *Microsoft 365 and Microsoft SharePoint* is the flexibility to adjust them to your particular needs. As the company participates in the management of significant projects of public and private investors, it applies its project management methodology to every single project and every investor, yet in the framework of its own methodology, based on international standards for project management (IPMA, PM^2, PMI) and ICT software and commercial software solutions, as well as proprietary models developed within *Microsoft 365 and Microsoft SharePoint*.

In line with the above guidelines (interoperability, wider applicability, security and data protection, and the possibility of adaptation to the needs of individual projects), we are open to adopting new, better and more efficient digital models, without which, we are convinced, it will not be possible to successfully develop and manage new, more complex and increasingly demanding projects in relation to the high quality, deadline, cost objectives, and other objectives that investors increasingly recognise and rank highly in their priorities.

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Artificial Intelligence Prognosis Model for Timing the Heavy Maintenance of Road Bridges

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Abstract:

Most road bridges in Germany were built between 1965 and 1985 and have therefore exceeded more than the half of their life span of 70 to 100 years. Due to this fact, to the actual condition of some road bridges, and to the steady increase of the heavy traffic the demand e.g. for heavy maintenance or replacement works as well as the bridge investment costs will rise significantly in the next years. Each damage of a bridge is detected, documented and graded according to the criteria of stability, road safety and durability in building inspections which are carried out in cycles pursuant to DIN standard 1076. The resulting heavy maintenance or replacement works are characterized by a reactive management approach, which is finally not economical. The challenge is to transform this reactive into a proactive management approach based on a new developed artificial intelligence prognosis model for the early determination of the point of time for the required heavy maintenance or replacement works. The focus in this paper is to describe the main challenges concerning the development of the artificial intelligence prognosis model (e.g. main influence factors for the determination of the point of time for the required heavy maintenance or replacement works, required data and the availability, quality, format and interfaces of data). In future, this proactive management approach should improve the forecast quality, the corresponding estimation of a more stable and predictable investment budget, the efficiency of the design and the following heavy maintenance or replacement works.

Keywords: *road bridges; artificial intelligence prognosis model; timing of heavy maintenance work*

1. Introduction

Transport infrastructures and in particular road bridges are the economical veins of a country, they overcome natural and artificial obstacles, connect people and serve to transport goods. As engineering structures, they are an important part of the road transport network and are indispensable for the economy and the prosperity of the people. Approximately 39,500 bridges are currently located in the network of federal trunk roads in the transit state Germany. Most of these bridges were built between 1965 and 1985, after the Second World War and at a time when the burgeoning German economy demanded modern transportation routes. Many road bridges from this period, constructed with prestressed concrete, are prone to damage and in poor condition. (BMDV, 2019)

In addition to the age and the construction method, the reasons for the poor condition of the road bridges are manifold. The main reasons are the sharp increase in passenger and especially in freight traffic, which continues to rise. The increasing number of goods is transported over ever longer distances, with the result that road freight transport performance has grown nearly continuously over the past almost 30 years by 103 %, from 245.7 billion ton kilometres in 1991 to 498.6 billion ton kilometres in 2019. (Umweltbundesamt, 2021)

When the bridges were planned and build, the planners didn´t expect such an increase in traffic load, especially in heavy traffic. From today´s point of view a lot of the road bridges are not adequately dimensioned. As a result of the further increase in the age structure and in passenger and freight traffic, heavy maintenance bridge construction works on road bridges will continue to increase in the coming decades. This represents a major challenge for the bridge maintenance. To address these issues, the road construction authorities are seeking a shift from reactive to predictive maintenance. For this reason, the prognosis and plannability of the heavy maintenance bridge construction works, summarized as predictive maintenance is of great importance for many reasons; the road construction authorities can plan heavy maintenance bridge construction works earlier by the prognosis and provide the necessary personnel capacities and budgets accordingly. The traffic safety and control measures associated with the maintenance measures can be planned at an early stage and the duration of the maintenance measure are reduced due to the improved planning of the maintenance measures.

Technological development in the course of Industry 4.0, especially Artificial Intelligence (AI) has led to process optimization and has significantly improved many areas of industries such as manufacturing, retail and telecommunications. (Abioye, 2021) Manufacturers, service providers and plant operators can collect and evaluate data from technical systems and integrate it into business processes for e. g. predictive maintenance. Due to the ability of AI to make predictions, this technology is also expected to lead to progress also in predictive maintenance for timing the heavy maintenance bridge construction works in the future. The aim of this paper is to assemble the main challenges in developing an AI-based prognosis model as a first step for the digital transformation in the maintenance of road bridges.

2. Research methodology

The purpose of the research work is to develop an AI-based prognosis model for timing construction maintenance works of road bridges. This paper is intended to be the first step in the model development and presents an approach to derive data driven predictions of the condition ratings of road bridges linked with e. g. construction, inspection, traffic and climate data. To identify the main challenges for the development of an AI-based prognosis model for timing construction works of road bridges, a literature review is conducted, which can essentially be divided into two parts:

In the first step (chapter 3) the maintenance management of road bridges in Germany is going to be reviewed. In order to identify the current state of the art as well as the main challenges in road bridge maintenance, actual German standards and guidelines are analyzed. The analysis includes the "Engineering Structures in the Course of Roads and Streets - Monitoring and Inspection" (DIN 1076), the "Instruction Road Information Bank - Structural Data Segment" (ASB-ING), the “Guideline for uniform detection, assessment, recording and evaluation of results of inspections” according to DIN 1076 (RI-EBW-PRÜF) and the "Guidelines for the Strategic Planning of Maintenance Measures on Engineering Structures" (RPE-ING).

In the second step the technology of AI in general as well as the application of AI in the construction industry are examined (chapter 4). Articles from national and international journals, such as *Bautechnik* and *buildings,* were evaluated. First, a general understanding of the technology of AI has to be created in order to be able to identify the central requirements for developing an AI based prognosis model. Additionally, the applications of AI in the construction industry and the associated benefits are identified. Based on this, applications in bridge maintenance are specifically investigated. Based on the literature review of the state of the art in bridge maintenance in Germany as well as the basics, requirements and applications of AI, the main challenges concerning the development of the artificial intelligence prognosis model for the condition assessment of road bridges are identified and compiled in chapter 5.

Subsequently, for the development of the AI-based prognosis model the most important influencing factors for one selected bridge type have to be defined and weighted on a bridge- and component-specific basis. For example, the influence of traffic is not relevant for a bridge railing, but is significant for the road surface. Machine learning is to be used to teach the AI prognosis model with the learning method of supervised learning. In a decision tree, the corresponding path shall be followed according to its top-down structure. The major advantages of the supervised learning procedure are the traceability of the decision and the efficiency in the calculation. In an iterative process the AI prognosis model must be trained, optimized and evaluated with inventory data.

3. Maintenance management of road bridges in Germany

Bridge maintenance in Germany is divided into two parts in accordance with *DIN 1076*: the inspection and the monitoring of engineering structures. The inspections are the most important part of the bridge maintenance and carried out in defined inspection cycles. They are categorized into three inspection types: main inspections, simple inspections (visual inspections) and inspections for specific reasons (special inspections). Road bridges are to be inspected every sixth year by a main inspection and every three years after a main inspection by a simple inspection. Special inspections are only carried out after extraordinary events (e.g. after the end of every major flood or icefall, after fire under the bridge and after serious accidents). (DIN 1076, 1999)

Each damage is evaluated in the inspections by the building inspector according to the three criteria of stability (Stabilität (S)), highway safety (Verkehrssicherheit (V)) and durability (Dauerhaftigkeit (D)). The rating scale is between 0 (no influence on S/V/D) and 4 (S/V/D no longer given). The sum of the ratings of the individual damages results in the rating of the associated component group. The sum of the ratings of the component groups results in the partial structure rating (condition rating). The condition ratings are determined automatically by the calculation algorithm in *SIB-Bauwerke*. The condition rating is an indicator of whether a repair measure is to be planned in the near future and can therefore be used to identify the need for necessary measures to be taken as a matter of priority. No statements can be made about the type and extent of damage or the costs of repair and renewal measures. In principle, maintenance measures are to be initiated if the assessment of an individual damage is "$S \geq 3$ or $V \geq 3$". Maintenance management to date has been determined by a reactive approach. Due to reactive maintenance management, it is necessary to react under time pressure with negative consequences.

The results of the inspections are summarized in the inspection report. Each individual damage is recorded in the inspection, entered in the road information database structures, which is called *SIB-Bauwerke (SIB-Structures). SIB-Bauwerke* is a relational database in which the structure data is stored in 61 tables linked via a key field. This key field is the seven-digit structure number assigned to each road bridge. Structure data are the generic term and are differentiated in construction data according to *ASB-ING* and status data according to *RI-EBW-Prüf*. (WPM – Ingenieure GmbH, 2019) All these data are stored in *SIB-Bauwerke* and can be output in different document types: The construction book, the inspection reports and the condition report.

In addition to the inspections, the road bridges are monitored. In the monitoring of engineering structures, a differentiation is made between surveys and ongoing observations. Surveys are to be carried out regularly once a year and after extraordinary events without major aids such as survey vehicles and scaffolding. In the years when a main or simple inspection is carried out, the bridge is not surveyed. Obvious defects and damages are to be recorded. Ongoing observations are part of the general monitoring of the traffic route. The highway safety of the road bridge is continuously observed as part of the route inspections. Furthermore, all components are observed twice a year without special aids from traffic level and ground level for obvious defects and damage. Only significant defects/damages that could endanger the stability or traffic safety should be recorded. (DIN 1076, 1999)

Additionally, to the condition rating, the most important quantifiable factors for the maintenance management of road bridges are the *substance index* according to *RI-EBW-PRÜF*, which is composed of the stability and durability, and the *bearing load index* according to *ARS 09/2020*. The *bearing load index* was developed in 2020 as a "characteristic value for the structural assessment with regard to the sustainability of bridges" and is "a comparison between the target and actual load-bearing capacity of a (partial) structure". (BASt), 2020) The target load capacity depends on the road cross-section as well as the traffic volume and traffic composition and is defined as the *target load level*. The current bridge load-bearing capacity is referred to the actual *load-bearing capacity*.

Besides the operational measures, the guidelines for the strategic planning of maintenance measures on civil engineering structures (*RPE-ING*) provide an overview of structure maintenance, define maintenance strategies and show the process and framework conditions of strategic maintenance planning. Each maintenance planning is based on the structure data, which are recorded, managed and maintained in *SIB-Bauwerke* according to *ASB-ING*. According to *RPE-ING*, the data on the condition and age of the structure, the data on the location of the structure in the road network and the associated data on the traffic load are of particular importance for maintenance planning and the definition of the maintenance strategy. (*RPE-ING, 2020*)

4. Artificial intelligence in the construction industry

4.1. Definition Artificial Intelligence

Numerous definitions of AI can be found in the literature. The answer to the question of what is meant by AI is already difficult because there is no common opinion on how exactly to define intelligence. Basically, it is about creating computer programs or machines that are capable of behaving intelligently. (Kaplan, 2017) American computer scientist Elaine Rich defined AI as "Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better." (Rich, 1985) In particular the importance of temporal context to the definition of AI is illustrated here. As AI's capabilities evolve, the boundaries of what AI can even do continue to be pushed over the years (Kreutzer and Sirrenberg, 2019), so that their general - since particularly broad - definition of AI remains valid today. *Kreutzer and Sirrenberg* formulate a more precise definition: "Artificial intelligence refers to the ability of a machine to perform cognitive tasks that we associate with the human mind. This includes capabilities for perception as well as capabilities for reasoning, independent learning and thus independent finding of solutions to problems." (Kreutzer and Sirrenberg)

4.2. Performance components of AI

Now AI has become a marketing term under which many different terms are subsumed, which are often confused with each other or used synonymously. Neural networks, machine learning (ML) and the subfield of ML, deep learning (DL) represent the essential performance components of AI (see Figure 1). In addition to ML and DL, significant progress has been made in other subfields of AI. These include natural language processing, virtual assistants or robotic process automation, which opens up many new opportunities for industry. (Zhang et al., 2021)

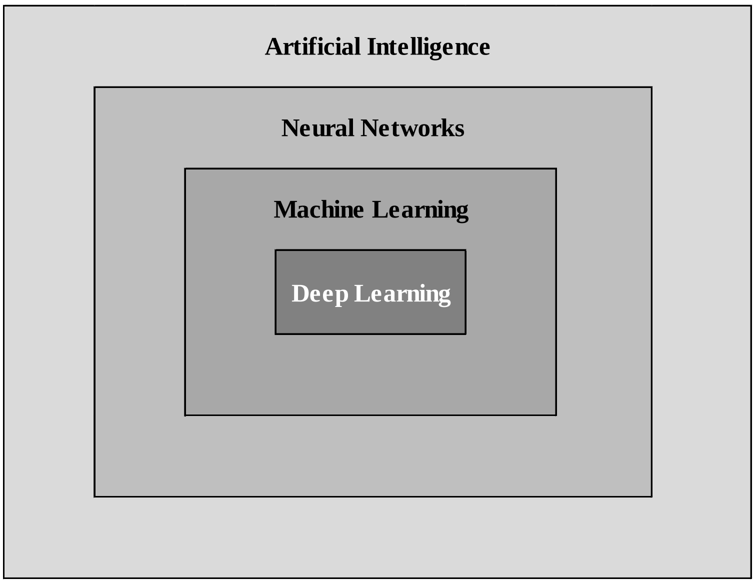

Figure 1. Performance Components of AI
(source: own representation based on Kreutzer and Sirrenberg, 2019)

In general, AI works "by combining large amounts of data with fast, iterative processing and intelligent algorithms [...], allowing the computer to learn automatically from patterns or features in the data." (Zhang et al., 2021) Neural networks, also dubbed the "masterpiece of AI" (Kreutzer and Sirrenberg, 2019), form the basis for AI.

These are computer algorithms inspired by and modeled on the functioning of the nervous system and, in particular, the human brain. (Kruse et al., 2015) An algorithm is generally "an instruction for action consisting of several individual steps to solve a problem." (Weber and Seeberg, 2020) Training data is required to build an algorithm. Thus, the algorithm can be applied to previously unknown data through training data. To be able to continuously check the algorithm, it is checked with input data. To improve the algorithm, feedback data is used to further train the existing algorithm based on previously collected experience (data). (Paaß and Hecker, 2020)

4.3. Machine learning

Machine learning (ML) is one of the central methods of AI, which "is concerned with the design and use of computer programs to learn from experience or past data for the purpose of modeling, control or prediction using statistical techniques without being explicitly programmed." (Abioye et al., 2021) In this process, the computer or machine continues to work with new algorithms, if they turn out to be more meaningful in the learning process than the algorithms initially used. This process takes place independently in machine learning, and the algorithms can learn independently and also improve as a result. (Kreutzer and Sirrenberg) ML is thus "a method that enables computer programs to learn from data without the need for explicit programming". (Weber and Seeberg, 2020)

In statistics, data is empirically analyzed to clarify what was (past). Data mining or Knowledge Discovery in Data (KDD) describes the process of identifying "patterns, associations, and correlations" (International business Machines Corporation (IBM), 2021) from large, qualified data sets (Big Data) to clarify why it is so (present). Machine Learning (ML) artificially generates knowledge from experience, i.e., data used to train the machine to learn specific tasks to clarify what will be (future). ML is thus a statistics-based method that uses algorithms capable of recognizing patterns in large amounts of data in order to derive conclusions for the future, for example, to avoid errors and increase efficiency. (Seeberg, 2019)

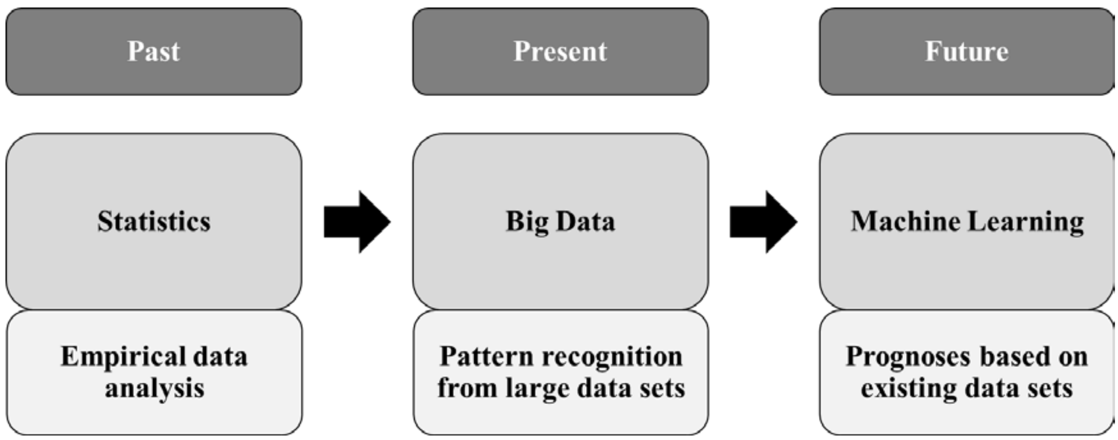

Figure 2. Differentiation between Statistics, Big Data and Machine Learning

The ML approach is also to be used for predictive bridge maintenance. On the basis of existing data (SIB structures), patterns are to be recognized, on the basis of which predictions for the future condition of the bridge or bridge elements can be concluded. In this way, the reactive maintenance strategy can be transformed into a preventive maintenance strategy.

4.4. Requirements for the use of AI

The essential requirement for the use of AI and the training of AI algorithms is a large and high-quality data set (Big Data), which is characterized by five features, also referred to as the "five Vs" (Kreutzer and Sirrenberg, 2019): I. Volume - the volume or the amount of data; II. Variety - the variety of data sources and types; III. Velocity - the speed with which data sets are generated, transferred, updated and deleted; IV. Veracity - the quality of the data; V. Value - the value or relevance of the data with respect to specific applications. (Keim and Sattler, 2020) Big Data usually consists of multiple data sources and is also largely fed by different types of data. The data is either structured (structured data is usually standardized data in relational database systems), semi-structured (semi-structured data can contain both forms of data) or non-structured (non-structured data is not structured via predefined data models such as text and image files) with non-structured data forming more than 80 % of company data. (Stuck, 2019) For AI, on the other hand, a structured form of data is to be strived; if data is standardized and centralized in databases, among other things, the timeliness of the data can be better secured and duplications and contradictions in the data can be avoided, since the input fields are clearly defined and all employees access the same database. The information content or quality of the data (veracity) can thus be describe as correctness (freedom from errors), completeness (coverage of all relevant fields), consistency (freedom from contradictions) and timeliness (validity of the data)". (Kreutzer and Sirrenberg, 2019) Before the data can be used for AI, the first step is to clean it. The process of correcting or removing data errors is referred to as "data cleaning". (Keim and Sattler, 2020) Data errors include "duplications, formatting errors [ ], or erroneous [ ], incomplete [ ] records [ ] in databases." (Keim and Sattler, 2020) Data cleaning should increase the quality of data. Combined with a sufficient data quantity and quality, the basic conditions for the use of AI are created.

4.5. Trends of AI in the construction industry

AI technology has already transformed industries such as manufacturing, retail, and telecommunications (Abioye et al., 2021), and its importance in the construction industry is also growing rapidly. However, the development of AI in the construction industry faces challenges such as "cultural barriers, high initial costs of employing AI-based solutions, incomplete data, trust, security, talent shortages, computing power and internet connectivity." (Abioye et al., 2021) Technological advances and the resulting emerging technologies in quantum computing, Internet of Things (IoT), cybersecurity, and blockchain (Abioye et al., 2021), as well as the "exponential growth of data, computing power and storage, and more advanced algorithms" (Zhang et al., 2021) have significantly improved the conditions for further AI development in recent years. Advantages of AI are seen in "increased cost and time savings, improved safety, better accuracy and overall increased productivity." (Abioye et al, 2021) With regard to ML, advantages are expected in particular in relevant predictive and prescriptive insights, increased efficiency, cost savings, improved safety, efficient utilization of resources and reduced mistakes and omissions. (Abioye et al., 2021)

Also, in the field of bridge maintenance or operation, some AI-based methods are being researched and also partly applied in practice. In particular, (partially) automated modeling of bridges in the inventory to generate a construction model and (semi-) automated damage detection are promising approaches for optimizing processes with the help of AI.

In the case of (semi-) automated modeling, tachymetry and photogrammetry methods are used to capture images of a bridge. With the help of corresponding BIM applications the generated point clouds can be transferred into a building model in a semi-automated way. (Borrmann et al., 2015) For this purpose, elements such as surfaces, cuboids or cylinders are inserted into the point cloud using special fitting algorithms. (Schwarz, 2017) Automation of the fitting process already exists to some extent today and will be further explored in the future. (Blankenbach, 2015) Furthermore, due to the advancing development of UAV (unmanned aerial vehicles) photogrammetry in particular offers great potential for modeling as-built models of bridges. Consequently, the flexibility, efficiency and accuracy of measuring and modeling three-dimensional objects (e. g. bridge structures) can be increased. (Blankenbach,

2015) An end-to-end system of 3D data collection, modeling and integration of the data into a BIM-enabled software is provided, for example, by the 3D collection tool from Faro in combination with the BIM-enabled modeling software Autodesk Revit. (Kaden et al., 2017)

Another topic area, in which significant progress has been made in recent years, is AI-based damage detection. This is used in bridge inspections and is intended to simplify and optimize the efficiency and quality of the inspection. Currently the condition of the structure is checked during regular inspections using classical methods such as manual inspection according to DIN 1076. The BASt research project 89.0334 dealt with the (semi-) automated image analysis using UAVs to support the visual inspection of bridges. This measurement method can be automated and enables image data to be obtained from high and difficult-to-access areas. From these image data the information of condition regarding the damage of the structure under consideration was then determined by using modern methods and algorithms. A key aspect of the project is the use of ML methods to develop a methodology for automated detection of damage such as cracks on concrete surfaces. In addition to numerous research projects, AI-supported damage detection is also already being tested in practice. For example, the start-up StrucInspect deals with AI-supported digital inspection for damage and crack detection, thus saving time as well as increasing the accuracy of the inspection. (StrucInspect, 2022)

One approach for bridge maintenance is provided by the work of *Naraniecki et al.* in which ML procedures are used to derive data-based prediction of the structural condition of railroad bridges. These predictions are intended to provide a basis for maintenance management. The basis of the data-based prognosis is the method of Building Information Modeling as well as digital building models in connection with operator-related inventory data.

5. AI prognosis model

5.1. Reasons for the development of an AI prognosis model

An AI prognosis model for timing the construction works in the heavy maintenance management of road bridges enables a predictive bridge maintenance management. The early plannability of the construction works offers several advantages: For example, the necessary personnel capacities and budgets can be planned and made available at an early stage and a continuation of the public budget planning is possible. Furthermore, a higher tendering quality can be achieved, which should, among other things, reduce the number of claims and increase the economic efficiency of the constructions works in heavy maintenance. In addition, construction companies are able to plan and provide the required capacities in a more efficient way, which has a positive effect on the final bid price.

Besides the economic effects, positive ecological effects can also be expected: The highway safety and guidance measures associated with the rehabilitation measures can be planned at an early stage, thereby minimizing the impact on traffic flows. Both, the economic costs and the CO2 and noise emissions resulting from congestion, detours, speed reductions and the duration of the rehabilitation measure are reduced due to the improved early planning of the infrastructure measures.

5.2. Main influencing factors on the condition of road bridges

In order to determine the timing of construction works in the maintenance management of road bridges, the influencing factors must be selected and weighted for one selected type of bridge and on a component-specific basis in the AI prognosis model. Depending on the type of bridge and component, the influencing factors are manifold - the number can range from 15 to 25 influencing factors. A selection of the influencing factors is shown in Table 1. These influencing factors can be classified into three areas: Bridge-specific, Component-specific and External.

Table 1. Influencing factors on the condition of road bridges

Influencing factors					
1	**Bridge-specific**	**2**	**Component-specific**	**3**	**External**
1.1	Type of bridge	2.1	Component type	3.1	Traffic volume
1.2	Age of structure	2.2	Year of installation of the component	3.2	Traffic composition
1.3	Structural system	2.3	Condition grade of the component	3.3	Weather and climate
…	…	…	…	…	…

Bridge- and Component-specific data are stored in *SIB-Bauwerke*. The most important external factors are the traffic volume and the traffic composition. Both are collected in the course of road traffic counts and summarized as the *ADT* (average daily traffic), which represents the traffic volume. (BASt, 2022) Not only the static loads of the vehicle types represent a load on the road bridge, but also the dynamic loads generated by the different load effects of the traffic resulting vibrations. The increasing heavy-load traffic in particular has an influence on the condition of road bridges (see chapter 1). The *ADTLV (*average daily traffic - light vehicle) and the *ATVHV* (average daily traffic - heavy vehicle) have to be evaluated in order to be able to determine the share of heavy-load traffic. (BASt, 2022)

5.3. Data basis of the road bridges

The most important data basis of road bridges is the *SIB-Bauwerke* program system. It was developed by the road construction administrations of the federal and state governments, which are also the owners of this IT product today. Before the development of the *SIB-Bauwerke* program system, building data in *NRW* (*North Rhine Westphalia*) were first recorded digitally in Microsoft's first operating system MS-DOS (Microsoft Disk Opera-ting System) from 1991. With the further development of the operating system from MS-DOS to Microsoft, the program system *SIB-Bauwerke* for Windows was developed in 1998. Building data have been electronically systematically recorded since 1998 in the first program version of *SIB-Bauwerke* (version 1.0). The data already recorded before the development of *SIB-Bauwerke* were not converted by MS-DOS in most of the regional offices in *NRW* and imported into *SIB-Bauwerke*, so that for a large part of the structures built before 1998 no inspection reports are available digitally. The construction data, on the other hand, have been added for the respective building in the meantime. (WPM – Ingenieure GmbH, 2019)

Road traffic census (*RTC*) has been carried out by the *BASt* (*Bundesanstalt für Straßenwesen*) at 5-year intervals on freeways and federal roads in Germany since 1960. In the course of the *RTC*, road traffic is recorded between April and October in accordance with the guidelines of the *BMVI*. Both the number and type of vehicles are determined. The traffic data are then transmitted to the *BASt*, which evaluates and checks them. The results of the *RTC* have been available in digital form since 2005. (Ministerium für Verkehr des Landes Nordrhein-Westfalen, 2022)

The exact location of the road bridge is known from the information in the *GIS* (Geographic Information System), meteorological data can therefore be recorded for specific bridges and used for AI. Data on climatic conditions have been collected on a large scale and in high quality by the German Meteorological Service (*DWD – Deutscher Wetterdienst*) since 1951 in *NRW*, and are available in structured form. (Straßen.NRW, 2022)

5.4. Main challenges in developing an AI prognosis model

The overall requirements for ML as well as the database of road bridges result in fundamental requirements for the development of an AI prognosis model. These requirements can be described by the five Vs: I. Volume; II. Variety; III. Velocity; IV. Veracity and V. Value (see chapter 4.4). However, to identify the requirements, which are listed in Table 2, the following key assumptions have to be made in advance:

- Determination of the bridge type: There is a large number of different bridge types, which are fundamentally different in their construction. Each bridge type has to be considered separately for the prognosis model, because the comparability of construction is a basic assumption for teaching the AI prognosis model.
- Determination of the bridge components and their respective damage patterns: In addition to the selection of a type of bridge, the associated components and their characteristic types of damage have to be defined too.

With these two mandatory assumptions, it is determined which type of bridge is to be considered in the prognosis model and which data has to be taught. On this basis, as well as the general requirements for AI listed in chapter 4.4, the main requirements for the developing of an AI prognosis model are listed in the following Table 2.

Table 2. Requirements for the developing of an AI prognosis model

Main requirements for the developing of an AI prognosis model	
I. Volume	**Acquisition of sufficient database to train the AI:** - Sufficient number of bridges - Sufficient number of types of damages - Sufficient number of acquired construction works in the maintenance management of road bridges - Complete data history

II. Variety	**Availability and procurement of the necessary data with different data formats from different databases:** - *SIB-Bauwerke* (database for building, inspection, condition data) partially structured data - Road traffic data (state traffic watch of the respective federal state) - Weather data (DWD - German Weather Service)
III. Velocity	**Velocity of data extraction from databases and data processing:** - Compatibility of the prognosis model to be developed with the existing databases for extracting and importing the existing data in a sufficient velocity for AI
IV. Veracity	**Ensuring or creating sufficient data quality:** - Objective bridge inspection - Completeness of the documentation of damage cases and construction works in the maintenance management of road bridges - Bridge inspection at regular intervals according to DIN 1076 - Consistency of the data (especially in *SIB-Bauwerke)* - Structured data - Timeliness and correctness of the data (chapter 5.2)
V. Value	**Checking the data value in the modeling stage:** - Component-specific determination and weighting of the main damage cases - Component-specific determination and weighting of the influencing factors - Component-specific determination and weighting of the construction works in the maintenance management of road bridges

Based on the main requirements, the main challenges for the development of an AI-based prognosis model are presented subsequently:

I. Volume: A sufficient amount of data is the basis for teaching, improving, and ultimately verifying the AI prognosis model. Sufficient influencing factors and condition values have to be available over the entire life span of the building. Due to the large number of bridges in Germany, an adequate amount of data should be available. The biggest challenge is to (manually) add the required data to *SIB-Bauwerke.* The structure data including the data of damage and maintenance measures have been recorded in the digital database only since the year 1998. This means that all bridges that have been in existence longer than 1998 have not been fully recorded. This represents the majority of bridges in Germany. The completion of the databases has been handled differently in the various federal states in Germany, so that the data stock before 1998 differs depending on the federal state.

II. Variety: The data for the prognosis model derive from different databases and are available in different data formats as well as partly unstructured. The main challenge in the variety of data is to identify the required data and make them available for the prognosis model.

III. Velocity: The speed of data transfer, especially from the interoperable database *SIB-Bauwerke* and data processing have to be checked first. In addition, it has to be examined at what speed of data cleaning can be carried out in order to extract the required data from the databases.

IV. Veracity: Component damages and maintenance measures are recorded by the building inspectors and documented in the central database. Mistakes can occur in the recording and assessment as well as in the documentation. This means, for example, that damages can be overlooked during the bridge inspection. In practice, already documented damages are checked in particular and small, new damages, that have not yet been documented, are overlooked more quickly and accordingly not recorded in the database. With an average life span of 70 to 100 years for road bridges, they are inspected by a large number of different building inspectors. The assessment of damages as well as the completeness and consistency of the documentation of the executed construction works depend on the subjective evaluation, competence and work experience of the respective bridge inspector. This means that the correctness and consistency in *SIB-Bauwerke* have to be checked before using the data in the AI prognosis model. The problem of subjective bridge inspections is addressed in some research work in which an attempt is made to automate or partially automate bridge inspection.

In this case, automated bridge inspection such as AI-based inspection of visible damage and automated data acquisition could probably lead to an increase in the completeness of the data in the future. In the next few years, for example, the use of UAVs, augmented/mixed reality systems, AI supported image recognition software in building inspections and the use of sensors in monitoring will enable significantly more data of bridges to be obtained. This data can be used for maintenance planning as well as for in situ monitoring of road bridges. By using digital twins in condition prognosis, comprehensive inventory data can be intelligently linked and used for the assessment. (Naraniecki et al., 2022)

Apart from this, some required data in *SIB-Bauwerke* are unstructured, not available, duplicated or not entered in the designated input field, so that the data basis has to be cleaned in advance. The process of correcting or removing data bugs like duplications, formatting errors and incorrect or incomplete data records in databases is called *data cleaning*. Data cleaning can increase the quality of the data. It is not yet possible to estimate how extensive data cleaning will be. In any case, generating sufficient data quality is a main challenge. In conjunction with a sufficient amount of data, the basic prerequisites for the use of AI are created.

In addition to the completeness and correctness, the timeliness of the data must be checked, especially in the maintenance management of road bridges. The data of the component damage, the maintenance measures, the traffic data as well as the weather data are permanently saved at corresponding databases. Damages of components are recorded at cyclical intervals in accordance with DIN 1076 every three to six years in the corresponding inspections. Area-wide traffic data are mainly collected every 5 years in the course of road traffic census. This cyclical data collection means that in individual cases the data may be outdated and therefore no longer useable. This problem could be counteracted by a more regular data collection up to a continuous data collection (monitoring) in individual cases.

V. Value: The challenge is to identify the value of the necessary data. Only in the course of creating and training the AI prognosis model, it becomes apparent which influencing factors improve the accuracy of the prognosis model to what extent.

6. Summary

For an economic maintenance management of road bridges constructions works should be planned predictively and proactively. By developing an AI prognosis model, the transformation from reactive to predictive life cycle management could be possible. From the perspective of the road construction authorities, the ability to plan construction works at an earlier stage enables, among other things, an improved budget planning, lower maintenance costs due to the higher quality of tenders and a reduction of claims. The construction companies are also able to plan at an early stage and provide the necessary personnel capacities at the appropriate time. In the stationary industry AI is already applied in the area of predictive maintenance and could be transferred to road bridges.

The main challenges in the development of an AI prognosis model are manifold and can be categorized into five areas accordingly to the five Vs (see chapter 5.4). Two of the main challenges to realize a successful working AI prognosis model are to increase the data volume and improve the existing data quality if it is not sufficient. The data volume can be increased by (manually) adding additional bridge data in a time-consuming process or by considering more data of influencing factors. The data quality can be improved by data cleaning.

Furthermore, the necessary data for the AI prognosis model are from different databases and in different data formats. These data have to be made available, selected, imported and weighted in a bridge- and component-specific way. In this context the correctness, completeness, consistency and timeliness of the structure data mainly depend on the subjective assessment and data maintenance of the different building inspectors. An improvement in the quality of data can now be realized in the process of data cleaning and in the future through technological developments in inspections and monitoring of bridges.

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Analysis of Two Real Life Project Management Case Studies Concerning Waste Management Projects in Croatia

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Abstract:

The project life cycle, from the point of various responsibilities and interests arising from its phases, is indisputably fragmented. Thus, for example, the designer of the conceptual design, the developer of the feasibility study, the developer of the environmental impact study or the developer of the procurement documentation do not generally have the same interests, rights, obligations or responsibilities in the implementation of the project. This is self-evident, but it is important to recognize the need to understand all phases of the project cycle and their causal links, the potential for risk transfer between phases, objectives and boundary conditions of the project, etc. This need must be met by timely engagement of the Project Manager. This paper uses a comparative analysis of two real life Project management case studies concerning Waste Management Projects in Istria and Šibenik-Knin County in order to try to answer the questions concerning (i) the optimal moment of engaging a Project Manager within the project cycle and (ii) the justification of appointing a Project Manager from the Employers own resources comparing to contracting an external consulting service all in relation to the required efficiency and expected results. Respecting the character, uniqueness, multidisciplinary nature and dynamics of the implementation of construction projects under the assumption of efficiency, proactivity and flexibility of the construction project management process, the following conclusions were made: (1) In order to ensure the optimal impact and contribution of the Project Manager on the realization of project objectives, the Project Manager should be engaged during the period of preparation of study documentation concluding with the feasibility study and cost-benefit analysis based on which the investment decision is made. (2) For the purpose of ensuring the optimal influence and contribution of the Project Manager on the realization of Project goals and ensuring efficient and flexible management of the construction project, it is optimal for the Project Manager to be engaged through an external consulting service.

Keywords: *waste management; Project Manager; construction project management; project life cycle; risk management; efficiency*

1. Introduction

There are various generic definitions and variations in the literature on the topic of what the project (life) cycle of a project implies, that is which phases and sub-phases it consists of. In general, it can be concluded that the project cycle of each project, including construction projects, consists of roughly 5 (five) basic stages or phases:

1. Phase: Project conception
2. Phase: Project planning

3. Phase: Execution or implementation of the project
4. Phase: Evaluation of project success
5. Phase: Closing the project

Bearing in mind specifically construction projects, following the implementation phase (construction works) usage phase and the demolition phase, which nominally comes at the very end of the project life cycle, would also be applicable.

The topic and goal of this paper is to compare two real life implemented construction projects and try to come to conclusions about the optimal time for the appointment of the Project Manager within the project life cycle. Also, the aim is to try to answer the question of the justification of the engagement/appointment of the Project Manager from client own internal resources (employee of the client) in comparison to contracting an external consulting service to do the job.

Thus, the analysis and review will be given from two points of view:

i. Timeliness of Project Manager appointment within the project life cycle

ii. Justification and efficiency of appointing the Project Manager from own resources in comparison to contracting an external consulting service

For the purposes of the analysis, two actual case studies will be used, that is two implemented construction infrastructure projects. The first case study refers to the construction of the County Waste Management Center "Kaštijun" in City of Pula (Project A) and the second case study refers to the construction of the County Waste Management Center "Bikarac" - Phase II in City of Šibenik (Project B). Considering that both cases represent construction projects of (County) waste management centers of relatively comparable complexity and needs in the form of project management activities and that both projects share basic input settings in terms of project life cycle elements, stakeholders, funding sources, ownership structure, strategic and legislative bases, applicable risks, etc. the necessary relative comparability is ensured.

2. Project A: County Waste Management Centre "Kaštijun", City of Pula

At the beginning of 2007, the County of Istria and the City of Pula established the company Kaštijun ltd. in order to prepare documentation for the establishment of a waste management system for the County of Istria and the construction of a waste management center as its central part. The goal was to establish a comprehensive waste management system in the Istria County, which basically consists, in infrastructure terms, of a waste management center "Kaštijun" and six transfer stations.

Waste Management Center “Kaštijun” consists of a waste treatment zone and an entrance-exit zone including landfill cells. The waste treatment zone consists of a mechanical-biological waste treatment plant including manipulative areas and accompanying infrastructure with a capacity of 90,000 tons per year. The treatment plant combines mechanical and biological treatment to stabilize waste, extract valuable recyclables and fuel from waste and reduce the amount of waste to be disposed of.

The entrance-exit zone with the landfill consists of a working zone and buildings (entrance building, scales, service center, wastewater treatment plant, recycling yard, etc.), while the landfill part consists of a cell for disposal of methanogenic fraction (after treatment), non-hazardous industrial waste cell and degassing system.

Figure 1. Bird's eye view of CWMC Kaštijun during the construction phase

The project was initially applied for and approved for funding at the end of 2009 under the Environmental Protection Operational Program 2007-2009 through the so-called IPA pre-accession funds of the EU that were available to the Republic of Croatia in the period before accession to the EU. Since these were EU pre-accession funds, the established company Kaštijun ltd was not allowed to apply directly for EU funds and additionally, in accordance with the applicable rules in that period, the (public) procurement procedure and project implementation had to be carried out through one of the accredited implementation agencies. In this case, the accredited implementing agency was the Environmental Protection and Energy Efficiency Fund (hereinafter referred to as the EPEEF) with the role to carry out public procurement procedures, implement the project under individual contracts and complete the handover of the project to the final beneficiary (Kaštijun ltd).

Figure 2: Bird’s eye view of CWMC Kaštijun during Trial Operation phase

Although EPEEF was already engaged in the period of preparation of the feasibility study, cost-benefit analysis and project application, nominally the Project Manager was appointed from internal resources only at the end of 2011. EPEEF, as the project holder and the one managing the project implementation, actively participated in the preparation of procurement documents including key elements of procurement such as terms of reference, particular conditions of the contract, employers’ requirements, terms of payment etc. EPEEF directly influenced the qualitative content of these key elements of works procurements during the planning phase. The implementation of the public procurement procedure as well as the subsequent implementation of the works contract confirmed that the procurement documentation, among other things, due to the influence and contribution of the Project Manager was balanced, clear and unambiguous in all its components. The works contract was contracted based on FIDIC Conditions of Contract for Plant and Design Build, 1999 edition (so-called "Yellow" FIDIC book). The accepted contract amount was € 26,718,469.34 without VAT with Time for Completion set 855 days from the Commencement Date which was February 1, 2012. Ultimately, the Taking-Over Certificate was issued on February 19, 2018, almost 4 (four) years after the Contracted Time for Completion. The Final Payment Certificate was issued to the amount of € 26,831,647.79 € excluding VAT, including the deduction of contracted Delay Damages in the (maximum) amount of 10% of the Accepted Contractual Amount.

Table 1. Overview of changes in the Accepted Contract Amount and Time for Completion during the implementation of the CWMC Kaštijun project

Project A - CWMC Kaštijun			
Initial Time for Completion (days)	Final Time for Completion (days)	Taking Over Certificate (date issued)	Time for Completion (days delayed)
855 days from Commencement Date*	957 days from Commencement Date*	2/19/2018	1255
Accepted Contract Amount without VAT	Contract Price after corrections without VAT	Final Payment Certificate without VAT	Δ Accepted Contract Amount and Final Payment Certificate
26,718,469.34 €	29,503,494.72 €	26,831,647.79 €**	+113,178.45 €

** Commencement Date 2/1/2012*

*** Final Payment Certificate amount with deducted Delay Damages*

3. Project B: County Waste Management Center "Bikarac" - Phase II, City of Šibenik

At the beginning of 2014, City of Šibenik established the company Bikarac ltd in order to prepare documentation for the establishment of a waste management system for the Šibenik-Knin County and the construction of a waste management center as its central part. The goal was to establish a comprehensive waste management system in the Šibenik-Knin County, which basically consists, in infrastructure terms, of a waste management center "Bikarac" and two transfer stations.

Waste Management Center “Bikarac” consists of a waste treatment zone including new landfill cells (phase II). The entrance-exit zone with existing landfill cells and the wastewater treatment plant was constructed through phase I of the project. consists of a mechanical-biological waste treatment plant including manipulative areas and accompanying infrastructure with a capacity of 40,000 tons per year. The treatment plant combines mechanical and biological treatment to stabilize waste, extract valuable recyclables and fuel from waste and reduce the amount of waste to be disposed of.

The project was initially applied for EU financing at the end of 2016 and approved in March 2017 under the Competitiveness and Cohesion Operational Program 2014-2020 through the so-called EU Cohesion Fund. Unlike Project A, given the applicable rules in the period after the accession of the Republic of Croatia to the EU, the established company Bikarac ltd independently submited an application for a grant agreement, independently prepared and implemented public procurement procedures and implements contracts arising from public procedures in the role of the Client in accordance with the provisions of the Public Procurement Act (OG 120/16). On April 18, 2018, Bikarac ltd signed a contract with the external consultant company for the Technical Assistance and Construction Project Management Services and officially appointed the Project Manager in accordance with the applicable regulation.

Figure 3: Interior of the mechanical-biological treatment plant during the test work on Bikarac

Unfortunately, given the terms of the signed contract, Bikarac ltd submits to the consultant an official invitation to start the execution of the service only on May 28, 2019, when effectively Project Manager was activated. In the case of Project B, the Project Manager nor the technical assistance and project management team did not participate in the preparation of procurement documents including work on key elements of procurement such as terms of reference, particular conditions of the contract, employer’s requirements, terms of payment etc. The Project Manager is engaged only for implementation phase (construction). Previously adopted settings and inputs limited Project Manager approach and was able to manage the project only within the pre-established framework.

The works contract was contracted, as for Project A, based on FIDIC Conditions of Contract for Plant and Design Build, 1999 edition (so-called "Yellow" FIDIC book). The accepted contract amount was HRK 196,263,949.00 without VAT (roughly 26,168,000 €) with Time for Completion set 882 days from the Commencement Date which was December 6, 2021.

Figure 4: Separated fraction of aluminum from mixed municipal waste during the trial work on CWMC Bikarac

Ultimately, the issuance of the Taking-Over Certificate is expected on September 5, 2022, which, at the time of writing, is within the contracted Time for Completion. The amount of the Final Payment Certificate is not known at the time of writing, but no significant deviations from the Accepted Contractual Amount are expected, that is deviations are expected within the planned acceptable limits.

Table 2. Presentation of changes in the Accepted Contract Amount and Time for Completion during the implementation of the CWMC Bikarac project

Project B - CWMC Bikarac			
Initial Time for Completion (days)	Final Time for Completion (days)	Taking Over Certificate (date issued)	Time for Completion (days delayed)
882 days from Commencement Date*	1152 days from Commencement Date*	9/5/2022**	0
Accepted Contract Amount without VAT	Contract Price after corrections without VAT	Final Payment Certificate without VAT	Δ Accepted Contract Amount and Final Payment Certificate
HRK 196.263.949,00 (cca 26,168,000.00 €)	HRK 197.166.549,54 (cca 26,289,000.00 €)	HRK 198.666.549,54 *** (cca 26,489,873.00 €)	HRK +2.402.600,54 (cca 320,347.00 €)

** Commencement Date 7/8/2019*

***Expected date at the time of writing*

****Anticipated Final Payment Certificate Amount after corrections*

4. Legislative framework

On December 24, 2008, the Architectural and Engineering Works and Activities in Physical Planning and Construction Act (OG 152/08, 124/09, 49/11, 25/13) entered into force, introducing in Chapter V) the concept of performing construction project management activities, including obligations, organizational form and conditions for performing construction project management activities. The provisions of the above-mentioned law, concerning project management, in practice have not come to life due to significant limitations high level set entry conditions and the fact that the construction project management activity could only be performed by a legal entity. Additionally, the obligation to appoint a Project Manager was not prescribed.

On July 25, 2015, the Works and Activities in Physical Planning and Construction Act (OG 78/15, 118/18, 110/19) (hereinafter: the Act) entered into force, effectively replacing the Architectural and Engineering Works and Activities in Physical Planning and Construction Act (OG 152/08, 124/09, 49/11, 25/13), which introduced the obligation for public contracting authorities/investors to appoint a Project Manager for public investments. The obligation was introduced only to those investors who, in terms of regulations governing public procurement, are considered obligated to public procurement. Among other things, the possibility is introduced that the activity of managing a construction project can be performed not only by a legal entity but also by a natural person. The obligation to appoint a Project Manager was introduced for the construction of infrastructure projects and other buildings with a total investment value of over HRK 10,000,000.00 excluding VAT and for buildings with a total investment value over HRK 50,000,000.00 excluding VAT.

In December 2018, through the amendment of the Act (OG 118/18), the conditions for the obligation to appoint a Project Manager were additionally clarified in such a way that public roads were separated and an investment value of over HRK 50,000,000.00 excluding VAT was added to them while for the construction of public buildings the total investment value was reduced to HRK 35,000,000.00 without VAT. Additionally, the obligation to appoint a Project Manager for investment in the simultaneous construction of several buildings that are partially or completely intended for housing, are built in the same city or municipality and have a total of more than a hundred apartments was introduced.

The first paragraph of Article 38 of the Act stipulates that *"The project manager is appointed by the investor in order to optimize the use of funds and time before making an investment decision and budget funds planning and to legally and qualitatively prepare the project and its successful implementation."*

In the context of this case study, for both projects, the period " *before the investment decision*" means the period of preparation of study documentation in the form of pre-feasibility study (early stage of project development), feasibility study, cost-benefit study and, to go even further, development of waste management strategies, spatial planning and other planning (e.g. waste management plans, etc.) documentation etc. These activities belong to the project planning phase that ends with an investment decision. Taking into account the projects from the case study presented in this paper, it is assumed that the legislator, when suggesting the period before making an investment decision, refers to the period of study documentation (environmental studies, feasibility studies; cost-benefit studies; cost-benefit studies) immediately preceding the investment decision.

Furthermore, the first paragraph of Article 33 of the Act stipulates that the activity of construction project management includes *"financial, legal and technical advice related to the design, construction, use and removal of buildings"* and *"financial, legal and technical preparation and planning of construction works regarding monitoring the implementation of that plan."*

It can be argued that although the Act calls for the appointment of the Project Manager as a natural person, from the stated comprehensive multidisciplinary nature of obligations under the provisions of Article 33 of the Act it is necessary to engage a team of experts to manage a construction project. Conducted public procurement procedures and good practice in the last 7-8 years, for the procurement of construction project management services, called for a larger number of so-called key and non-key experts which to a certain extent confirms the above given conclusion. It can be concluded with relative certainty that a 'team' is needed to manage the construction project in order to successfully fulfill the obligations prescribed by the Act.

The referenced legislation framework provides primarily a local (Republic of Croatia) context to the publicly procured construction projects. It presents a legally imposed obligation to the public contracting authorities/investors to hire a Project Manager. As Kartelo, R. Sjekavica, M. (2019) state European Union regulation have been clear for years about the necessity of ensuring systematic, organized and competent project management, from the intervention logic defined through Project Cycle Management, EU Directive 1303/2013, the Guide for creating feasibility studies, etc. The message about the importance of project management is also given through the Methodology for project management of the European Commission – PM (2016).

5. Comparative analysis

As stated in the introduction to the paper, the analysis and review is given from two points of view:

(i) Timeliness of Project Manager appointment within the project life cycle

(ii) Justification and efficiency of the Project Manager appointed from own resources in comparison to contracting an external consulting service

In the case of Project A, the Project Manager was engaged during the project planning phase. This enabled him to directly influence the feasibility study, cost-benefit analysis and project application, to participate in the preparation of procurement documents including key procurement elements such as terms of reference, particular conditions of the contract, employer’s requirements, terms of payment etc.

In the case of Project B, the Project Manager was engaged in the project implementation phase and did not participate in the preparation of the feasibility study, cost-benefit analysis and project application, preparation of procurement documents including work on key procurement elements such as terms of reference, particular conditions of the contract, employer’s requirements, terms of payment etc.

In the case of Project A, the Project Manager (natural person) was appointed from the Client's own resources, while in the case of Project B, the Client appointed the Project Manager (natural person) through an external construction project management consulting service.

Table 3. Comparison between the number of contractors' claims and disputes initiated before the Dispute Adjudication Board

	Project A	Project B
Contractors’ claims	25	4
Disputes initiated before the Dispute Adjudication Board	5	0

5.1. Timeliness of appointment of the Project Manager

Strictly speaking, in accordance with the provisions of the Act and the theory of project management, the Project Manager should be engaged in the phase before making an investment decision in order to directly influence the optimization in the form of applied project solutions, applicable resources, project risks, etc. The Project Manager in the case of Project A, although not yet officially appointed at the time, had a direct influence on the activities and preparation of the documentation that preceded the investment decision. In the case of project B, the Project Manager was hired after the investment decision was made and thus had no influence on the activities that preceded the investment decision. In order to understand the optimal approach to the analysis, it is necessary to determine which are the key activities of the phase preceding the investment decision. The project life cycle, when we talk about this case study, means a period of over 10 years starting from the project conception phase (Waste management plans of local (regional) self-government units, spatial plans, pre-feasibility study, etc.) to the project closure phase (Taking over, warranty periods, use of the building, etc.). Practice has shown that the phases of the cycle of these public infrastructure projects are long, especially in the initial project conception phase. In the case of Project A, the beginnings of the project start-up date back to 2006 (waste management plans), while for project B the same goes back to the past as the first phase of the project was funded through ISPA pre-accession funds (2006). When concluding on the timeliness of the appointment of the Project Manager, having in mind the specifics of the projects of this case study, the aforementioned circumstance was taken into account.

For the purpose of maximizing the influence and contribution of the Project Manager on the realization of project goals, it is indisputably necessary to appoint a Project Manager before making an investment decision, as is the case for Project A. However, long duration of activities in initial phases, restrictions arising from public procurement legislation, funding conditions, etc. raises the logical question of the optimal time of appointment (engagement) of the Project Manager. In practice, firstly concerning projects in this case study and then other similar infrastructure projects, the influence of the Project Manager in the initial activities of the project conception phase is of lesser extent, especially related to the adoption of spatial planning and other planning documentation. In the period of preparation of study documentation such as pre-feasibility studies, environmental impact studies, cost-benefit analyses and similar studies, the Project Manager can significantly influence the project objectives. Taking into account the current practice in contracting the project management services in the public sector, Project Manager is rarely engaged before investment decision is made.

In conclusion, as a minimum, the involvement of the Project Manager should be ensured latest during the preparation of the procurement documentation including the preparation of general and particular conditions of contract and, in the case of projects that are implemented trough design build concept, during the preparation of employer's requirements.

5.2. Project Manager appointment from own resources in comparison to contracting an external consulting service

Article 38 of the Act prescribes the obligation to appoint a Project Manager in such a way that the investor (client) may contract the project management service with a person (legal or physical) registered for the project management activity or appoint a Project Manager who is an employee of the investor (client) and satisfies set requirements. In the case of Project A, the Project Manager was appointed from the client's own resources, while in the case of Project B, the client appointed the Project Manager through an external construction project management consulting service. In the case of Project A, the Project Manager (natural person) relied on the internal professional services of the client (EPEEF), especially regarding legal, public procurement, financial and accounting elements of contract implementation. In the case of Project A, the client nominally appointed a project management team from its own resources. The appointed experts, in accordance with the strict hierarchical or functional organizational structure of the client, were directly responsible to their superiors. The project manager did not have the authority over nominated experts nor he was able to manage expert resources (time).

In the case of Project B, the Project Manager (natural person) is appointed from a team of contracted external experts through a construction project management consulting service. The project management team contracted through the construction project management consulting service consisted of four (4) so-called "Key" and six (6) "non-key" experts. The Project Manager had the authority over the engaged experts and had the experts' resources appointed to the project.

For the purpose of maximizing the influence and contribution of the Project Manager on the realization of project goals, it is indisputably necessary to ensure an efficient and flexible decision-making system and ensure rapid qualitative and quantitative analysis of project situations with targeted and concise expert input. This is secured to a greater extent in Project B project management setup. The outsource option seems as a generally favorable way to go as also recognized by De Witt, S., Yakowenko, G., Bohuslav, T., Ferguson, T., Hoelker, E., Molenaar, K., Schiess, G., Smythe, J., Triplett, J., Wagman, R. (2005) concluding that public sector (in this study highways) are moving more towards consultant involvement in contract administration.

Respecting the character, uniqueness, multidisciplinary nature and dynamics of the implementation of construction projects, the assumption of efficiency, proactivity and flexibility of the project management process is a kind of *conditio sine qua non* for the successful realization of the project.

6. Conclusion

The aim of this paper was to effectively compare two real life implemented projects and try to reach conclusions concerning:

(i) the optimal time to appoint the Project Manager in the project life cycle, and

(ii) justification and efficiency of the Project Manager appointed from internal resources in comparison to contracting an external consulting service

Given the narrow range of samples in this case study and the specifics of the boundary conditions of the analyzed projects, the goal was not, nor could it be, unambiguously and indisputably provide answers that would be horizontally applicable to (all) construction projects. However, drawn conclusions, at least in principle, should be applicable nevertheless.

Regarding the timely (optimum) engagement of the Project Manager, in the case of the case study analyzed here, it is concluded that the Project Manager should be engaged during the period when preparation study documentation is prepared including the feasibility study and cost-benefit analysis based on which the investment decision is to be taken. As a minimum, to ensure the impact and contribution of the Project Manager in relation to resource optimization, risk management, establishment of project and contracts boundary conditions, engagement must be ensured during the preparation of procurement documentation including general and special conditions of the contracts and also during the preparation of any terms of reference and/or employers' requirements. Actions from the Project Manager engaged only for the construction and implementation phase are limited by the previously adopted settings and inputs and he is able to manage the construction project only within the pre-established framework.

It is important to realize that the project life cycle in respect to various responsibilities and interests arising from project phases is indisputably fragmented. Thus, for example, the designer of the conceptual design, the developer of the feasibility study, the developer of the environmental impact study or the developer of the procurement documentation do not generally have the same interests, rights, obligations or responsibilities in the implementation of the project. This is of course self-evident, but it is important to recognize the need for understanding all phases of the project life cycle and their causal links, the potential for risk transfer between phases, objectives and boundary conditions of the project, etc. This need must be met by timely engagement of the Project Manager.

Regarding the justification of appointing a Project Manager from internal resources in comparison to contracting an external consulting service, in the case of analyzed projects and related to the required efficiency and expected results, it would be optimal to engage a Project Manager through an external consulting service. The prerequisite for successful construction project management is an efficient, fast and flexible decision-making process. Public contracting authorities are often unable to meet this assumption due to limitations arising from the functional organizational structure and the lack of specialized knowledge, skills and even experience. Experiences from the analyzed Project A confirms the above conclusion, where due to the lack of project management team "project ownership" sentiment, insufficient understanding of every day project situations and slow and highly bureaucratic decision-making process, the project fell into a series of problems, into substantial number of claims and disputes and, ultimately, a significant breach of contract deadlines.

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Calculation of Construction Machines Work Cost Depending on Age of Machines

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Abstract:

The costs of work for the construction machinery change with time and in such a way that the machinery ownership costs decrease, the exploitation costs increase and the overall costs most often show a decrease in the first years of operation and, after reaching their minimum, increase all the way to the end of a machine's working life. The impact of a change in the cost of construction machinery operations can have a significant impact on a range of tasks, such as the formation of an optimal fleet of machinery, a plan for machine maintenance, machine replacement planning, and many others. In order to accurately determine the costs of machinery work over time, it is necessary, first and foremost, to look at what costs change over time and in what way. In additional, it is necessary to define a working life of a machine, exploitation hours by year and assume all the direct costs during the work's life. The primary goal of the paper is to provide an insight into the real costs and the optimal planning for the construction machinery replacement, as well as calculate for the moment of minimum costs of work for the construction machinery. In this paper, the theoretical approach to this problem is tested with data on the real costs of construction machines collected from construction sites in Serbia. On the basis of the measured values of costs, mathematical models for calculating the change of costs over time have been proposed.

Keywords: *construction machinery; work costs; machine replacement*

1. Introduction

As the basis for a variety of financial planning and capital budgeting decisions, machine replacement planning is an extremely important part of long-term business planning. There are many criteria by which a decision can be reached for the replacement of machinery. In the majority of cases, the basic criteria is based on the operating costs of the machine during its working life. "How much does it really cost me?" and "How long do I keep it?" are two question for which there is no precise answer to in practise. However, these answers are crucial for the economic justification to maintain ownership of construction machinery. If a machine is owned and operated for a short period of time then owning costs arising from high early depreciation dominate the calculation and give rise to high hourly rates. On the other hand, if the machine is kept for too long then hourly operating and maintence costs tend to increase.

The optimal economic ownership period or "sweet spot" in practice is recognised as the period when the sum of hourly owning and operating costs have been minimsed. In other words the sweet spot is determined as the period when the machine has worked long enough to reduce owning costs, but not long enough to experience unnecessary or unusually high operating costs.

2. Problem statement

Planning a fleet of construction machines is one of the most complex logistical problems of a construction company. In this process, it is necessary to optimize several criteria, the most important of which are:

- Investment costs in new construction machines should be minimal
- Machine maintenance costs should be minimal
- The cost of construction machinery should be minimal
- Profit based on the operation of construction machinery should be maximized.

In order to optimize these criteria, it is necessary to assemble the fleet of machines correctly, which means that it is necessary to determine which machines need to be acquired, how many of them to keep and when to get rid of them. The issue of purchasing machines is a matter of work technology, while for other issues the basis of the problem lies in the fact that the costs of operating machines change over time. In order to optimally form and maintain a fleet of machines, it is necessary, first of all, to look at how the costs of operating the machines change over time.

The goals of this work are:

- Determine what constitutes the operational life of machines
- Define how machine operating costs change over time
- Show how a fleet of machines can be formed in accordance with the change in the operating costs of the machines over time.

3. Working life of machines

Machine life can be defined in three ways: as physical life, as profit life and as economic life. Figure 1 shows how the relationships of these three time phases are defined. At the end of the service life, the machine is usually replaced. It is up to the owner of the machine to see how he wants to view the service life of the machine and to define the criteria for deciding that it is necessary to get rid of the machine. In order for this decision to be made correctly, it is necessary to define and apply the criterion of the end of the working life of a construction machine.

3.1. Physical Age

The physical life of a machine is the age of the machine after it has worn out and can no longer be used reliably. When worn out, it is usually sold or remelted in scrap iron. During this age, maintenance and operating costs increase significantly. How much the costs of operating the machine will increase depends on the way the machine is operated, the nature of the work and the quality of maintenance and care that is applied. It is believed that the introduction of low costs for regular maintenance eliminates the need to spend large amounts of money to replace the main components of the machine. Thus, with two completely identical machines, with completely identical parts, the physical age can differ significantly depending on the method of maintenance and the severity of the working conditions in which they are used.

3.2. Profit Life

Profit life is the time during which a machine makes a profit. Using the machine outside of that phase leads to the creation of costs higher than the profit that the machine made. In essence, this is the period when the machine actually spends more time in service than on the construction site, expensive repairs increase and profit decreases, because the main components are successively consumed and have to be replaced. Therefore, it must be established when a certain machine is approaching that point, or has already reached it, and plan to replace it with a new machine, while the main components are still in operation.

3.3. Economic Age

Economic life is the period in which maximum productivity is achieved, when the machine reaches the point of greatest profit. Machine owners are constantly striving to maximize performance at minimal cost.

Figure 1 illustrates the practice in which the economic life of a machine is shorter than the physical life and ends when the profit generated by that machine reaches its highest value. Therefore, if the machine is replaced on time, the drop in profitability due to increased maintenance costs is prevented. Owners can, if they closely monitor maintenance and repair costs, determine the exact time to replace the machine. Determining the optimal time to replace a machine requires that the machine owner include in the analysis not only the cost of ownership and operating costs, but also all other costs associated with owning the machine. These costs include depreciation costs, inflation, investment costs, maintenance and repair costs, downtime losses and obsolescence costs.

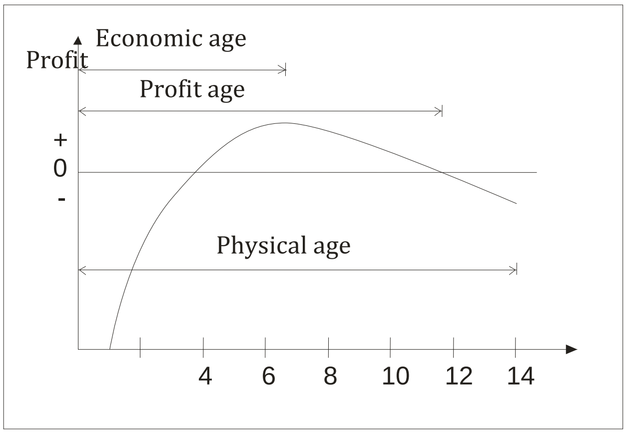

Figure 1 – Economic, profit and physical age

4. Calculating Costs Over Time

Determining the period when operating hourly costs (sweet spot) are at a minimun and calculating the peak of construction machinery costs requires a detailed understanding of owning and operating costs and how these vary over the life time of a machine. There are several important factors to consider:

1. Owning and operating costs, by their own nature, are very different;
2. Hourly owning costs decrease over time;
3. Hourly operating costs increase over time;
4. Hourly cost calculations are overly sensitive to changes in input parametres.

The relationship between cost per hour and machine age is extremely complex and is based on numerous assumptions which need to always be confirmed in practise. To obtain the correct results requires calculating hourly costs during the working life of the machine. This is only possible if a correct prediction is made about the work life of the machine and the anticipated hourly periods of operation during every year of utilisation. A detailed presentation of the process is shown in literature (Petronijevic P. et al, 2010.).

In order to analyse the change in operating costs of a machine during utlilisation requires an analysis of how individual costs change during the operating life of a machine. Total direct lifecycle costs is the sum of primary resource costs (Eos) and operating costs (Eex) enlarged by the coefficient non-utilisation, D, that is, the costs a machine incurs in downtime according to the formula:

$$Ch = (Eos + Eex) * (1 + Down) \qquad (1)$$

where:

C_h - total of hourly costs,
E_{os} - primary resource costs
E_{ex} - operating costs
D_{own} - percentage of non-utilisation

Primary resource costs represent owning costs. They include the sum of depreciation costs(*Eam*), investment maintence costs (*Eio*) and interest and insurance costs. (*Ekios*).

Operating costs represent the costs of construction machine operations. They are the sum of energy sources and lubricant costs (*Ee, Emaz*), labour costs (*Ers*), repair parts costs (*Eh*) and current maintence costs.(*Eto*). A detailed calculation of these costs is shown in Petronijevic P. et al. (2010.).

Total costs are calculated according to the formula in (1). Costs which are rarely included in the calculation, but nonetheless have a significant impact on total operating hourly costs, include costs incurred when the machine is inoperable due to a malfunction and non-utilisation at the building site.

Over time, primary resource costs (owning costs) decrease, but total operating costs increase.Their sum, combined with cost of non-utilisation over time, is simply presented by the U-shaped curve. In the first years of operation cost decrease, reach a minimum, and after this, costs begin to increase and continues to do so until the end of work life of the machine. Changes in costs over time are graphically displayed in Figure 2.

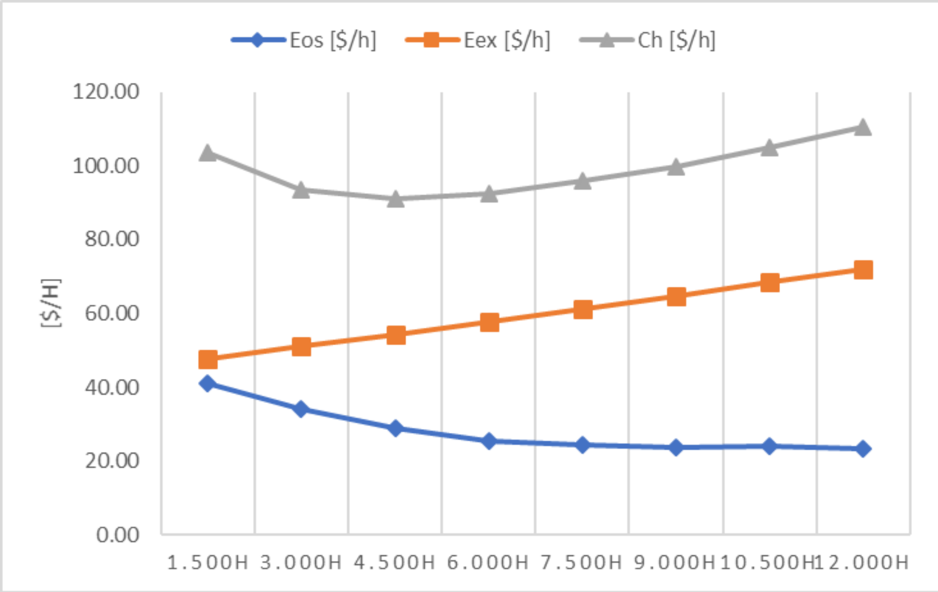

Figure 2. Changes in owning costs, operating costs and total costs during the work life cycle of a machine

According to Vorster (Vorster, 2010.), before analysing total operating costs during the work life of a machine, it is necessary to consider the following data:

- Magnitude of the minimum point – It is necessary to determine what are the minimum total operating costs of construction machines;
- The timing of the minimum point - This is important data which shows how long the machine should be kept in ownership in order to minimise the sum of decreasing owning and increasing operating costs
- The shape of the curve – This information confirms and quantifies the sensitivity of the cost calculation on either shortening or lengthening the life of the machine and makes it possible to set ranges or zones used as a basis for machine replacement planning.

One of the most important uses of this calculation is to compare the real cost to the optimal planning point for the replacement of machinery. Machine replacement planning is extremely important strategically for construction companies as it forms the basis for financial resource planning and capital budgeting decisions.

5. Methodology in fleet replacement planning

5.1. Definisanje metodologije

Fleet replacement planning is based on the economic price of a machine. This can be divided into five steps:

1. Determine the curve and changes in operating hourly costs during utilisation
2. Define acceptable age cost zones, that is, determine the moment when the machine should be replaced (sold, shelved….)
3. Rank and group machines according to age
4. Plan utilisation of every machine over time according to expected work hours
5. In accordance with costs groups, plan replacement and acquirement of new

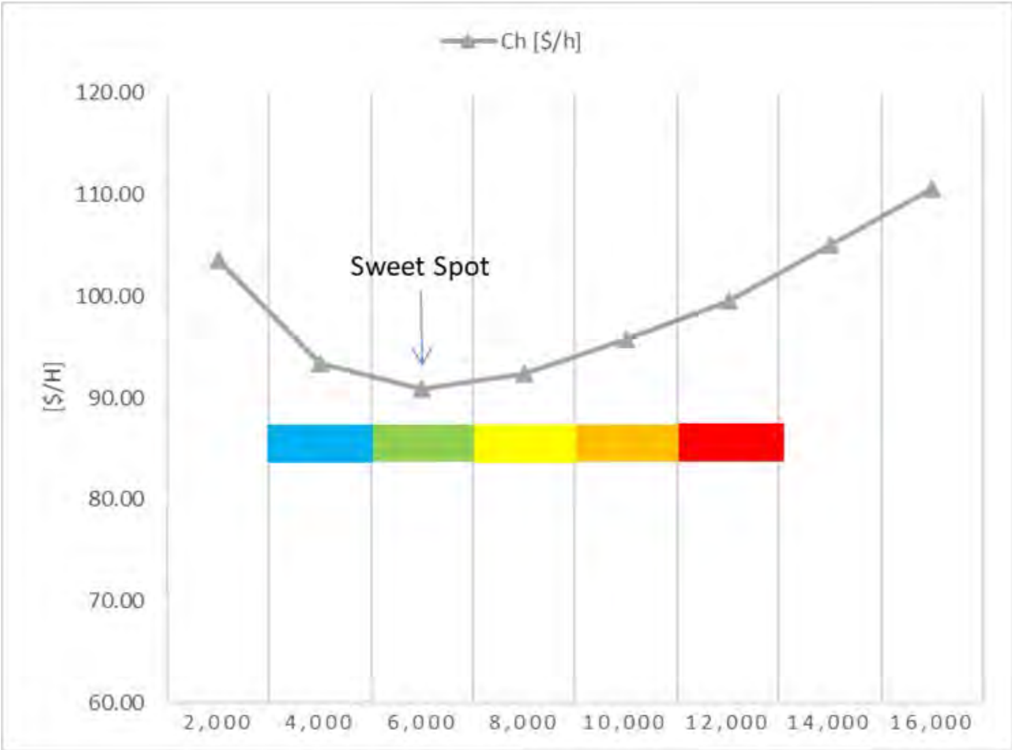

Figure 3. Position and magnitude of sweet spot and division of cost zones.

6. Example of fleet replacement planning

Figure 3 shows the cost curve over time as calculated using the formula (1). The position of the Sweet Spot is 5.000 working hours. Working under the assumption that such a curve is acceptable for all machines, the cost curve zone can be grouped into five zones.

- Blue zone - below 4,000 hours. The machines are young and have not yet reached their minimum point. In this zone, Ownership Cost is still significant, while operating costs have not risen.
- Green zone – from 4,000 to 6,000 hours, (1,000 hours each side of the Sweet Spot) . This is the most economical zone - operating costs in this zone are at a minimum.
- Yellow zone - from 6,000 to 8,000 hours. Machines in this zone are slightly past the minimum and are becoming expensive to operate due to increasing operating costs.
- Orange zone – from 8,000 to 10,000 hours. Machines in this zone are clearly becoming more expensive due to rising repair costs and increasing fuel costs.
- Red zone – from 10,000 to 12,000 hours. Machines in this zone are clear candidates for replacement due to high operating costs which dominate while Ownership Cost are less and less.

By way of illustrating this methodology, an analysis of a replacement plan for a fleet of 11 machines in varying age zones has been given (from 3,010 working hours to 11,450 working hours). The plan is shown in Table 1. Every machine has been assigned an hourly per annum plan in the range from 1,500 to 2,100 hours. In the column Current Age the number of working hours which a machine will have by the end of 2018 is shown.

All machines have been grouped according to their work life in the column Current Age (Table 1). This column represents the age of machines at the end of 2022. Years are expressed in the number of working hours. In accordance with the division of cost zones, 2 machines are eligible for the red zone and are being planned for sale. The number of working hours by the end of 2023 is represented by the sum total of working hours for the current year, 2022, and planned hourly operations per annum (Hours per year). In the column for 2023., the two machines which were in the red zone in 2022. have been sold and two new ones have been bought. The same process is repeated for the following year. The total age of machine, expressed in the number of working hours of machines, in this way, remains relatively stable. Also the average age of machines is relatively stable and ranges from 5,876 hours to 7,180 hourse, that is, it is mainly in the yellow cost zone.

The development of long term strategy of machine replacement consists of a moderate mix around machines in all zones which have a suitable average age. In figure 7.4 it can be deduced that three machines are in the red zone.. If two machines are sold and immediately two new ones are purchased then a mix like in column C is obtained.. If this is not done then 4 enter the red zone and the firm will be confronted with a major problem in machine planning replacement in the following year.

If existing machines were replaced with new ones, the average age of machines would be significantly higher (shown in Table 2). In this case, the machines would rapidly (as early as 2024) enter the red cost zone and their operating costs would be expensive.

Table 1. Plan machine replacement over a four year period

			Expected age at the end of			
Unit ID:	Hours per year	Current age	2023	2024	2025	2026
A450	1500	18,550	<Sell			
A310	1500	16,200	<Sell			
A371	1800	14,520	16,020	<Sell		
A455	1800	13,100	14,900	16,700	<Sell	
A230	2000	12,080	14,080	16,080	<Sell	
U5620	1800	11,230	13,030	14,830	16,630	<Sell
U5630	1500	10,200	11,700	13,200	14,700	16,200
U5635	1500	9,090	10,590	12,090	13,590	15,090
U5624	2000	8,100	10,100	12,100	14,100	16,100
A556	2000	7,120	9,120	11,120	13,120	15,120
A548	1800	5,100	6,900	8,700	10,500	12,300
G325	1500	Buy>	1,500	3,000	4,500	6,000
G225	1500		1,500	3,000	4,500	6,000
G247	1800		Buy>	1,800	3,600	5,400
U2569	1800			Buy>	1,800	3,600
S256	2000			Buy>	2,000	4,000
S456	1800				Buy>	1,800
	Total:	125,290	109,440	112,620	99,040	101,610

Table 2. Plan machine replacement over a four year period if no sale of old and buying of new machines is done

Unit ID:	Hours per year	Current age	Expected age at the end of: 2023	2024	2025	2026
A450	1500	11,450	12,950	14,450	15,950	17,450
A310	1500	10,220	11,720	13,220	14,720	16,220
A371	1800	9,100	10,600	12,400	14,200	16,000
A455	1800	7,230	9,030	10,830	12,630	14,430
A230	2000	6,800	8,800	10,800	12,800	14,800
U5620	1800	6,540	8,340	10,140	11,940	13,740
U5630	1500	6,050	7,550	9,050	10,550	12,050
U5635	1800	4,550	6,350	8,150	9,950	11,750
U5624	2000	4,020	6,020	8,020	10,020	12,020
A556	2000	3,580	5,580	7,580	9,580	11,580
A548	1800	3,010	4,810	6,610	8,410	10,210
Total age:		72,550	91,750	111,250	130,750	150,250
Average age:		6,595	8,341	10,114	11,886	13,659

7. Conclusion

A specific example shows the methodology of forming and maintaining a fleet of machines based on changes in the costs of machine exploitation over time. The model proposed by Vorster (Vorster, 2010) and Douglas (Douglas, 206) was fully confirmed.

Apart from the age of fleet, there are other factors which influence machine replacement planning. The average age of machines and the level of investment in replacing machines enables the firm to remain productive and be competitive in the future. The magnitude of the fleet and the age of the fleet are two very different things. One relates to the present, while the other to the future. Both are very important and deserve more attention.

The impact of a change in the cost of construction machinery operations can have a significant impact on a range of tasks, such as the formation of an optimal fleet of machinery, a plan for machine maintenance, machine replacement planning, and many others. In order to accurately determine the costs of machinery work over time, it is necessary, first and foremost, to look at what costs change over time and in what way. In additional, it is necessary to define a working life of a machine, exploitation hours by year and assume all the direct costs during the work's life. Also, the analysis of costs should include changing the reliability of machines over time.

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Research Methods for Analyzing the Influence of National Cultures on Organizational Culture in Construction

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Abstract:

According to Brown (1995), there are three main sources of organizational culture – national culture, type of economic activity, and founder or dominant leader inside an organization. The main purpose of this article is to identify the appropriate scientific methods for analyzing the influence of national culture on organizational culture in construction. More precisely, this article presents qualitative and quantitative methods for answering the following questions: first, how strong is the influence of national culture on organizational cultures in construction companies and on organizational cultures of faculties of civil engineering? Second, what is more important: the type of economic activity or the national cultures in which these organizations operate? The first part of the article describes existing literature about the interaction between national and organizational cultures. The second part presents quantitative and qualitative methods for measuring national and organizational culture. The third part proposes the application of research methods to the analysis of organizational culture in construction. The final product of this article will be a questionary for empirical research about the interaction between national culture and organizational culture in construction. This questionary should identify differences in attitudes of managers who work in construction, based on their national cultures. In addition, empirical research should identify differences in values between people who work in academia (in the field of construction) and those who work in construction companies. Finally, empirical research will also include an analysis of the differences in attitudes toward power distance and individualism based on gender and age.

Keywords: *organizational culture; national culture; research methods; construction*

1. Introduction

According to Brown (1995), there are three main sources of organizational culture – national culture, type of economic activity, and founder or dominant leader inside an organization. According to The Business Dictionary, national culture is “the set of norms, behaviors, beliefs, and customs that exist within the population of a sovereign nation.” There are numerous definitions of organizational culture. It is out of the scope of this article to present them. Therefore, only the definition used in this article is presented. According to Jones (2004: 195). Organizational culture is “the set of shared values and norms that controls organizational members’ interactions with each other and with people outside the organization.”

The main purpose of this article is to identify the appropriate scientific methods for analyzing the influence of national culture on organizational culture in construction. The role model for this research is Geert Hofstede’s book Culture’s Consequences (2001), a seminal book in this field. In his book, Hofstede compares the functioning of IBM branches in forty countries around the world. Analyzing the same company in different national settings, Hofstede isolated the independent variable (national culture) and examined the influence of this variable on organizational culture. Accordingly, this article proposes methods for the analysis of organizational cultures in construction in different national settings.

2. National cultures and organizational cultures

Since Hofstede's work is the basis for this article, his main finding will be presented first. He differentiates national cultures on the basis of five dimensions: power distance, uncertainty avoidance, individualism versus collectivism, masculinity versus femininity, and long- versus short-term orientation. It is out of the scope of this article to present all five dimensions. However, two of them are the most important for this analysis. Hofstede (2001: 214) has found huge national differences in attitudes toward individualism in IBM branches in different countries. Individualism has the highest level (based on Hofstede's index) in the United States (index 91), Australia (90), and Great Britain (89); the lowest index has Guatemala (6), Ecuador (8), and Panama (11). In other words, the first three countries are extremely individualistic and the latest three are extremely collectivistic. It should be repeated that these differences occur in the same company (IBM). Obviously, the type of activity is much less important than the national settings in which this company operates.

Similarly, huge differences between national cultures also exist in the field of power distance. In national cultures with a low distance of power, people do not hesitate to challenge the authority. In contrast, in national cultures with a high distance of power those who have power are considered special types of people. Subordinate people have almost unlimited trust in the ability of powerful people. Once again, Hofstede developed instruments for measuring the distance of power in different national cultures (index of the distance of power). Differences among national cultures, based on this index, are also huge. To illustrate, Austria has an index 11, Israel 13, and Denmark 18. On the other side of the spectrum are Mexico (81), the Philippines (94), Panama and Guatemala (95), and Malesia (104). Obviously, countries with huge power distance are clustered in Latin America and Asia.

In a similar type of research, Andre Laurent (1983) analyzed inclination toward authoritarianism in different national cultures. He has found tremendous differences among nations in this field. To illustrate, just 10 percent of the respondent in Sweden answered positively to the statement "it is important for the manager to have precise answers to any question that his or her subordinate can ask about the job." In contrast, 78 percent of respondents in Japan support this statement. It can be concluded that in Japan people tend to respect the authority of their superiors much more readily than in Sweden. Furthermore, subordinates in Japan expect superiors to solve problems and this fact leaves less initiative for subordinate workers. Accordingly, Laurent (1983: 77) concludes that the national origin of managers „significantly affects their views of what proper management should be."

Does it mean that type of activity does not influence organizational culture? Is organizational culture completely determined by national culture? Empirical research shows that answers to both questions are negative. For example, Helmreich and Merritt's (1998) study showed that pilots have a much more individualistic attitude than IBM employees (in the same national culture). The same difference also exists between pilots and medical doctors. In other words, organizational culture is a product of interaction between national culture and occupation. Accordingly, it is worthy to analyze the influence of national culture on organizational culture in construction. Furthermore, it is also important to analyze peculiarities of organizational culture in construction in comparison with organizational cultures of other occupations inside the same national culture.

Hofstede (2001: 23) provides methodological instructions concerning the appropriateness of comparison:

It is obviously not very meaningful to compare Spanish nurses with Swedish policemen… We can compare Spanish nurses with Swedish nurses, or Spanish policemen with Swedish policemen… With a fourfold sample of Spanish and Swedish nurses and Spanish and Swedish policemen, we can test not only the national effect but also the occupation effect…

Accordingly, the main purpose of this article is to formulate an appropriate methodology for comparison between people who work in construction in different national settings (cultures), and methodology for comparison between people who work in academia (on faculties of civil engineering) and people who work in construction companies. The second analysis should include people from the same national cultures. The empirical part of the research will also include differences in attitudes based on gender and age.

3. Organizational culture in construction

There are numerous articles about organizational culture in the construction business. It would be out of the scope of this article to present all the elements of this culture. Therefore, this article will focus on one important element – the level of authoritarianism in organizational culture in construction. In this field, it is especially important to mention Charles Handy (1979) and Fons Tropmenaars (1994). These authors differentiate organizational cultures focused on a hierarchy from cultures based on egalitarianism. Authoritarian organizational cultures assume strict control of subordinate workers, who do not have autonomy. Subordinates should simply obey the orders of powerful people inside the company. In contrast, egalitarian organizational cultures allow autonomy and discretional power of subordinate workers. In egalitarian cultures, communication goes in both directions – from top to bottom and from bottom to the top. It should be stressed that neither hierarchical nor egalitarian cultures are universally applicable. It would be not just illogical, but also inefficient to apply strict hierarchical culture in an academy of art. Similarly, no military in the world is based on egalitarian culture. Different occupations demand different cultures in general and different types of power structures, as an element of organizational culture (see Chatman and Jehn, 1994, and Deal and Kennedy, 1982). (Antić, 2019)

So, is the organizational culture in the construction business closer to an authoritarian or an egalitarian culture? Research conducted by the Faculty of civil engineering, University of Zagreb, provides an unequivocal answer: organizational culture in construction is similar to military, i.e., to authoritarian culture. Haladin (1993: 252) found that "on building sites we have frequently methods of control similar to those in military… Semi-military hierarchy and discipline are combined with patriarchal and informal elements of the organization." Haladin's study is now a bit outdated. However, the study by Šandrk Nukić and Huemann (2016) confirmed his finding. According to the authors, construction companies in Croatia currently function with the domination of the hierarchical type of organizational culture.

Furthermore, the study identified the clan as the preferred culture type in Croatian construction companies. If now we connect research about the differences of national cultures with the research about organizational cultures in construction (focused on the level of authoritarianism) we may hypothesize that those national cultures which accept high distance of power as normal, even desirable, can be the abundant reservoir of the working force in construction, especially reservoir of unskilled workers. Of course, additional empirical research should give proof for this theoretical assumption. (Antić, 2019)

Some statistical data also support this assumption. For example, construction companies in the USA hire a huge number of unskilled workers from Lain America. According to the United States Department of Labor (2014) (United States Department of Labor, 2015), 27.3 percent of workers in construction were of Hispanic or Latino ethnicity although Hispanic and Latino workers constitute just 16.1 percent of the working force in the USA. Of course, one of the reasons why so many workers in construction are from Latin America is also connected with their educational level. However, there is no doubt that organizational culture in construction matches the national culture of these workers. Accordingly, construction workers from Latin America can accept organizational culture in construction companies more easily than other immigrants to the USA and more easily than Americans themselves, who do not accept power distance equally as Latin American workers (Hofstede’s index for the USA in 40 and for Mexico 81). Furthermore, very workers from Latin American countries perform well in an authoritarian type of organizational culture. According to Janjićijević (2013: 616), the productivity of workers in Mexico is higher when leaders implement an authoritarian style of leadership than when they implement a democratic style of leadership. Accordingly, workers from Latin America do not have problems with the authoritarian style of leadership in the construction business.

Despite abundant literature about the organizational culture in construction, there is no replication of Hofstede’s research in construction. In other words, there is no research that compares the attitudes of people who work in construction based on the national culture in which these construction companies operate. Therefore, the main aim of this article is to propose appropriate instruments for comparing these attitudes.

4. Methods of analyzing organizational culture

There are two methods of analyzing organizational culture: quantitative and qualitative. Janićijević (2013: 224) summarizes the differences between these two methods: “Quantitative research methods are based on measurement whereas qualitative methods are based on description… Quantitative methods are founded on questionaries and statistics.” Hence, an appropriate questionary is the main prerequisite for quantitative research about the influence of national culture on organizational culture in construction. It is mentioned above that this article is focused on two dimensions of organizational culture in construction: power distance and individualism versus collectivism. Therefore, an appropriate set of questions should be formulated in order to measure the influence of national culture on attitudes toward power distance in construction.

4.1. Power distance

Attitudes toward power distance will be analyzed on the basis of the following questions proposed by Laurent (1983: 86):

1. It is important for the manager to have precise answers to any question that his or her subordinate can ask about the job.
2. An organizational structure in which certain subordinates have two bosses should be avoided at all costs.
3. In order to have an efficient work relationship, the hierarchical line should not be bypassed (The original Laurent's question is „In order to have an efficient work relationship, it is often necessary to bypass the hierarchical line”. Here, this question is reformulated in order to have the same order of responses in favor of the power distance.).

Respondents will have the option to answer these questions based on Likert’s scale (1-5), where 1 means that the respondent totally disagrees with the statement, 2 means that he/she disagrees, 3 means that the respondent neither agrees nor disagrees, 4 means that respondent agrees, and 5 means that respondent totally agrees with the statements above.

Obviously, answer 5 on the questions above shows a positive attitude toward power distance. Answers to the second question also enable a comparison of attitudes toward matrix-type of organizational arrangements. These questions enable a comparison of attitudes based on national origin, type of activity (academia versus work in construction companies), gender, and age. Furthermore, these questions will enable the comparison of answers of people who work in the field of construction with people who work in other professions because the overall results will be compared with Laurent’s ((1983) empirical research, which included people from various professions.

4.2. Individualism versus collectivism

According to Hofstede (2001: 209), “some animals, such as wolves, are gregarious; others, such as tigers, are solitary. The human species should no doubt be classified with gregarious animals, but different human societies show gregariousness to different degrees.” To illustrate, 47 percent of people in Sweden live alone (Flash Pack, 2022). Similarly, 23 percent of children in the USA live with just one parent. In contrast, the same figure is just one percent in Afghanistan and Mali, and two percent in Turkey (Single-parenting is considered only in the case that no other relative, except mother or father, lives with children) (Statista, 2020). But why these data are important for business? Hofstede (2001: 237), once again, provides the answer to this question:

The hiring process in a collectivist society always takes the in-group account. Usually, preference in hiring is given to relatives, first of all of the employer, but also of other persons already employed by the company… In the individualist society, family relationships at work are often considered undesirable, as they may lead to nepotism and a conflict of interest. Some companies have a rule that if an employee marries another employee, one of them has to leave.

In a collective society, the relationship between employer and employee resembles a family relationship. This type of relationship is best known in Japanese organizations. In contrast, in the individualist society, the relationship between employer and employee is considered a business transaction, without much emotional engagement. When an employee is fired, a common expression is that “this is not personal.”

In short, the previous research showed that national culture has a strong influence on organizational culture. Accordingly, it is important to check whether a similar pattern also exists in construction. In order to do it, it is important to formulate the appropriate questions for the survey. Hofstede (2001: 472-4) provides an extensive list of questions for checking attitudes toward individualism versus collectivism. For this survey, one question is the most important: “Decisions made by individuals are usually of higher quality than decisions made by groups” (respondents should express their agreement with this statement with Likert’s scale from 1 to 5). Hofstede also mentioned in his book ((2001: 226, 236) numerous other criteria for differentiation between individualistic and collective national cultures. For this survey, two additional questions are selected:

“Company is responsible for employees” versus “Employees are responsible for themselves.” Here, respondents can select whether they agree completely with the first statement (1), mostly agree with the first statement (2), do not agree either with the first or the second statement (3), mostly agree with the second statement (4) or strongly agree with the second statement (5).

The second pair of statements is the following: “Parents should live with their children in their old age” versus “Parents should live apart of their children in their old age.” Once again, respondents can express whether they agree with the first or with the second statement with the same pattern as in the previous question. Here, attitudes toward family relationships reveal also general attitudes toward individualism/collectivism.

The covid-19 pandemic showed huge differences between people who have individualistic attitudes toward the prevention of this and other diseases versus people who prefer a collectivistic approach. Therefore, in order to be up to date with the actual discussions about this topic, an additional question will be formulated: “Prevention of Covid-19 disease (vaccination and wearing a mask) should be based on individual decisions” versus “Government has a duty to punish those people who do not want to vaccinate and wear masks.”

With these four questions, attitudes toward individualism versus collectivism will be checked. Altogether, the questionary will include only seven questions, but this parsimonious approach should increase the number of people willing to participate in the survey.

5. Sample

The survey, with the questions mentioned above, will be conducted with the participants of three congresses – 15th International Conference Organization, Technology and Management in Construction, Senet Conference International Project Management Association, and International Project Management Croatia Young Crew Project Management Workshop. It is expected that approximately two hundred participants, from six continents and thirty countries will attend these conferences. This sample will enable a comparison of attitudes of people who work in construction and those who teach at universities in the field of civil engineering as well as a comparison of attitudes of people from different national cultures, gender, and age.

6. Further research and Conclusion

This article is a part of incremental research. Here, the methodology for analysis of the influence of national culture, type of activity (academia versus praxis in construction), gender, and age on organizational culture. The second step will be a survey, based on the questionary presented in this article. This survey will show whether above mentioned independent variables have an influence on the attitudes of people who work in construction. Accordingly, the second part of the research will show which type of organizational culture is the most appropriate in different national settings. For, Hofstede's work proved that organizational cultures should be adjusted to national cultures and attitudes of employers and employees. Furthermore, this second part of the research will show whether people who work in construction differ from people who work in other branches of the economy. In short, this research will show the interaction between national culture and the type of activity (construction). The results of this research may help to establish appropriate organizational cultures in construction in different national settings. Or, vice versa, if research shows that there is no significant difference, based on nationality, it may help to identify a universal organizational culture, based on the peculiarities of construction itself.

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Appendix (Questionnaire):

DO YOU WORK IN THE CONSTRUCTION BUSINESS: YES-NO

DO YOU WORK IN ACADEMIA: YES-NO

NATIONALITY:

PRESENT NATIONALITY (IF DIFFERENT FROM ORIGINAL):

GENDER:

AGE:

Would you be so kind, please, to answer the following questions? This survey is a part of research about the influence of national culture on organizational culture. All the answers are confidential.

Respondents have the option to answer these questions on the basis of Likert's scale (1-5), where 1 means that the respondent totally disagrees with the statement, 2 means that he/she disagrees, 3 means that the respondent neither agrees nor disagrees, 4 means that respondent agrees, and 5 means that respondent totally agrees with the statements above.

1. It is important for the manager to have precise answers to any question that his or her subordinate can ask about the job.	1 2 3 4 5
2. An organizational structure in which certain subordinates have two bosses should be avoided at all costs.	1 2 3 4 5
3. In order to have an efficient work relationship, the hierarchical line should not be bypassed.	1 2 3 4 5
4. Decisions made by individuals are usually of higher quality than decisions made by groups.	1 2 3 4 5

Here, respondents can select whether they agree completely with the first statement (1), mostly agree with the first statement (2), do not agree both, with the first and with the second statement (3), mostly agree with the second statement (4) or strongly agree with the second statement (5).

5. Company is responsible for employees.	1 2 3 4 5	Employees are responsible for themselves.
6. Parents should live with their children in their old age.	1 2 3 4 5	Parents should live apart from their children in their old age.
7. Prevention of Covid-19 disease (vaccination and wearing a mask) should be based on individual decisions.	1 2 3 4 5	Government has a duty to punish those who do not want to vaccinate and wear masks.

Cultural Awareness Education – A Prerequisite for Construction Professionals Entering Megaprojects

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Abstract:

Western consultants must build trust filled relationships if they wish to successfully engage with the local project sponsor to manage Gulf Cooperation Council (GCC) megaprojects. Research indicates that there is a high staff turnover for senior western consultants during the execution of GCC megaprojects. This research has found churn rates of up to 50% of senior construction professionals in megaprojects throughout the GCC. European megaproject research also finds that culture has a powerful influence on the construction of megaprojects, and cultural clashes negatively impact their execution. This paper reviews how engagement with the softer managerial skills such as cultural awareness, by examining the concepts of culture, national culture and professional culture, may benefit the megaprojects execution through the potential reduction of high levels of senior management churn. Researchers to date have helped identify typical characteristics of national culture, offering guidance for differing attitudes with respect to trust and cultural norms between different nationalities. This research analyses the experiences of the western consultant's actively involved in live GCC megaprojects. The findings show that cultural differences account for a substantial rate of churn, and acknowledges how cultural awareness has a crucial impact on both the megaprojects success and the consultants continued project engagement. The practical and social implications for western consultants' cultural integration are examined. The findings clarify that culture shock (both social and professional) is a significant factor for the rates of staff churn, and professionals need better preparation for cultural integration into the multinational megaproject arena. The project directors promote better cultural awareness, better candidate preparation, and an understanding of the fundamental cultural differences as a means of reducing unacceptably high rates of churn. The research also promotes gaining a greater understanding of specific elements of cultural mistrust during the megaprojects execution to help unite parties within these temporary megaproject coalitions and assist with the successful delivery of future megaprojects.

Keywords: *prerequisite training; cultural awareness in megaprojects; megaprojects delivery*

1. Introduction

Mega-projects are typically characterised by their long project duration, a complex contractual nexus, technical complexity requiring specialist skills, and the need to create a temporary project organisational coalition for the design, management, execution and delivery of the project (Flyvberg, 2017; Li et al., 2019; McKinsey, 2015). Such projects require large numbers of professional consultants as part of this temporary project coalition. A skills shortage in the professional services necessary for the volume of projects in the GCC has led to professional consultants mostly being appointed from outside the GCC - predominantly from Western Europe and North America. Individual consultants are generally employed on such megaprojects by large multi-national construction consultancy firms on fixed-term contracts.

National restrictions on land ownership and access to finance mean that in the GCC, the project sponsors are in every case nationals of the country in which the project is carried out. This sponsorship has given rise to two related issues. Firstly, that which arises at the national cultural interface, and secondly that which occurs at the professional/lay client interface. These issues are in practice inexorably linked.

Professional groups control a body of knowledge which is applied to specific tasks (Elliot, 1972 p 11). The project sponsors control the land, the capital, the regulatory framework, and the terms under which the professional consultancy service is provided. This professional/laity 'power relationship' requires a high degree of mutual trust to give this business efficacy. In addition to this professional relationship, for mega projects, in the GCC there is the added complexity of the social/cultural interface with western consultants, arising from differing belief systems, social and cultural norms, and rules and traditions governing status, interpersonal conduct and business relationships. The research uncovered that when cultural differences raise tensions which simmer or remain unresolved, senior western consultants are often removed from the megaproject – their contract is terminated. These losses can result in significant disruption and cost to the project, including non-financial elements such as the loss of essential project knowledge, the need to procure and contract with new personnel, and the need for induction and initiation in the project process and procedures. The study finds that cultural differences account for a significant proportion of senior Consultant staff turnover.

The individual experiences of western consultants actively involved in GCC megaprojects are the subject of this research, which examines the relationships between national culture and professional culture. The study aims to add to the current body of knowledge by providing an objective and measured contextual analysis of the impact of cultural differences and levels of trust on the successful delivery of the contractual obligations typically undertaken for GCC megaprojects. This field-based research attained the perspectives of 34 practicing project directors actively engaged in a wide range of megaprojects throughout the GCC. The research findings expose how cultural dissonance leads to a high project director churn rate, contributing to losses to all parties (including the individual consultant and the consultancy firm), project knowledge leakage, and delays.

Cost analysis of the research findings suggests that megaprojects can accrue additional cost overruns of up to $6 million per month, solely related to programme management fees, through associated project delivery delays.

The paper begins by defining culture awareness and setting this within the context of the GCC This introduces the concepts of culture and positions the paper within the existing body of literature and studies of national culture within the GCC. The paper reviews current research on European megaprojects and the findings from these which may be replicated in GCC megaprojects. The process of 'cultural integration' is evaluated together with an examination of the validity and usefulness of the application of conceptual cultural measurements developed by Geert Hofstede (G. J. G. Hofstede et al., 2002). Finally, the paper sets out the methodology applied in this empirical investigation into GCC megaprojects. The discussion considers possible implications in practice and suggests future research directions and the limitations of the work to date.

2. Contextual background to Cultural Awareness

Cultural conflict has been identified in megaprojects such as the Panama Canal expansion, the OMEGA megaproject in France (a French high-speed rail system), Eclipse (a network associated management of large infrastructure projects in Europe) and Nabucco (a 1,300 km pipeline through Turkey, Austria, Bulgaria, Romania, and Hungary). The studies identify how cultural acceptance is a critical factor for completing megaprojects (Rafindadi et al., 2014; Suprapto et al., 2016; Van Marrewijk et al., 2014). Biesenthal, Clegg, Mahalingam and Sankaran, (2018); Smits and Brownlow (2017) and van den Ende and van Marrewijk (2015) express how those cultural tensions amongst the management team are a significant risk that requires "special consideration" and management throughout the lifecycle of the megaproject.

Merron (1988) found that cultural factors can contribute to a megaprojects' failure, strongly recommending that cultural risk be considered in all future megaprojects. Van den Ende and van Marrewijk (2015) show different forms of cultural threats, including differences in national culture, organisational culture, or professional culture, suggesting that megaprojects are essentially cultural phenomena. While the risks of cultural dissonance disrupting the planned execution of the programme has been examined, few studies have attempted to assess the potential costs arising from cultural dissonance.

GCC project sponsors contract with large numbers of firms from outside the GCC to carry out the construction works for megaprojects Over nine million expatriate construction staff are employed on GCC mega-projects (World Bank, 2019), creating a multicultural delivery team (Dulaimi & Hariz, 2011) drawing from a pool of highly qualified resources around the world (El-sabek, 2017).

Based on the pronounced cultural differences typical on GCC Megaprojects (by contracts to European megaprojects which are typically more mono-cultural), this paper argues that current megaproject management research has not focused on the potential significance and effects of GCC megaproject cultural differences to date.

In Arabic culture, cultural bonds often centre around existing personal or family relationships. These hierarchies of trust have been described as being initially to self; then to a kinsman, townsman, tribesman; and finally to those with a shared religious background (Meyer, 2014, p. 171; Moran et al., 2011, p. 260). Lewis, (2016, p. 146) demonstrates the nature of this relationship hierarchy through a ‘trust circle’, with family at the centre and foreigners forming the outer perimeter. The aim of this is to provide a complete understanding of culture and trust influences in GCC megaprojects, and the possible implications of this for successful project delivery.

3. Consultants Professional Culture

Western consultants engaged in GCC megaprojects are appointed to provide their particular professional knowledge and expertise, to supplement or replace local consultants. Foxwell, (2019, p. 14) describes the expert in the consultant industry as someone with ‘a knowledge base, institutionalized training, accreditation, peer control and a code of ethics’ and that the services provided ‘need to be independent, …. free of bias and have the all-important commitment to the greater good’ (Foxwell, 2019). Expectations of high levels of competence and expertise are not limited to the GCC. Two wide-reaching government-sponsored studies into the UK construction industry, "The Egan Report", (1998) and Latham's "Constructing the Team Report", (1994) highlighted the confrontational approach typically found in construction projects. Foxwell notes more generally that there is a breakdown in trust in almost all institutions, and particularly in the opinion of ‘experts’. (Foxwell, 2019).

In positive settings, the trust generally grows as the parties become more familiar with each other, and as the professional working relationship develops. Meyer (2014, p. 190) describes how a good personal connection is the single most important factor when doing business in the Arab world. Familiarity is also described as a precondition for cultural harmony (Lewis, David J., Weigert, 1979).

3.1. Megaproject leadership culture

Megaprojects require the project leader to demonstrate strong business acumen, a high level of experience in the construction industry, and specific knowledge of delivering megaprojects. The project leader often needs to show specific skills in a particular type of project. Typically, the Project Sponsor will mandate a list of critical personal and project-specific criteria to 'headhunt' the appropriate people they require to increase the chance of successful project delivery. These criteria depend on the project's requirements, social, political and regional needs. The criteria for selecting project directors to lead megaprojects typically include high experience and education entry barriers; usually, the job specification requires a Master's Degree in Engineering or related technical field, in conjunction with a broad technical and construction background and registration with a professional body. It is generally also required that the project director demonstrate at least 20 years of experience in large-scale complex programs in a senior management capacity. These requirements are needed as megaprojects are often unconventional projects requiring exceptional management and leadership skills. Flyberg suggests that ‘if the project leader of a conventional project involves the equivalent of a driver's license to do what they do, then managers of megaprojects need a pilot's jumbo jet license’ (Flyvbjerg, 2014).

In addition to professional and field-related experiences, it is suggested that megaproject delivery requires a healthy spirit of collaboration as a prerequisite factor for megaproject success (Kardes et al., 2013a). Work by Biesenthal et al. (2018); Smits & Brownlow (2017); van den Ende & van Marrewijk (2015) interrogated the performance of existing megaprojects and identified that cultural issues amongst the management team leadership and governance were a critical risk that requires special considerations and management during the lifecycle of the megaproject. Mišić & Radujković (2015b) researched factors contributing to megaproject success or failure and suggested that culture is a critical driver for the successful completion of megaprojects. They asserted that the cohesive group performance of the delivery team is essential to its success. Zein (2016) describes how the unique combination of cultures gives rise to potential tensions within the organisation, describing this combination of cultures as a 'cultural soup'. Struggles & Heindrick (2015) highlight the need for leadership of such culturally diverse groups, in order to integrate and unite teams associated with megaprojects.

4. Conceptual Background to Culture

Culture has been described as a fuzzy, complex and inconsistent phenomena (Alvesson, 2002; Schein, 2004). There are many varied interpretations of culture (see for example GLOBE, 2004; Schein, 2004; Trompenaars & Wolliams, 2003) such as the 'systemised and deep-rooted beliefs and core values held by individuals and nations' (Kendall, Gavin, Wickham, 2001).

This research considers culture as a set of shared national or professional beliefs such as Inglehart's description of culture as *a set of norms and skills that are conducive to survival in a given environment,* (Inglehart, 2018, p. 16). Culture itself is considered as both invisible and intangible, and there is considerable complexity in measuring what anthropologists label as "beliefs" "values" or "dynamic phenomena" (G. Hofstede, 1991; Koopman et al., 1999; Schwartz, 2012). The ability to capture and define culture leads to this being a contested term, and critics such as Mcsweeney, (2002, p. 90) suggest that one is "*attempting to measure the unmeasurable".* Other anthropologists suggest that there are tools available that may be helpful in measuring culture (G. Hofstede et al., 2010; Smith, Peterson, & Schwartz, 2002; Spony, 2014).

4.1. Measuring Culture

Waisfisz (2015) suggests that culture only exists by comparison, and therefore, providing a benchmark score for each country, may permit comparisons to be drawn. Although potentially reductionist, one method of measuring 'culture', is by deconstructing a set of elements that are deemed to form part of a holistic approach to "culture", through the identification of unique features (or sub-sets). The sum of these sub-sets provides a global outlook considered as a "national culture". Different scholars have applied different and often unique labels for their sub-sets, variously describing these as "dimensions" (Hofstede and Pedersen, 2002) or "values" or "orientations" (K. & Strodtbeck, 1961). Scoring mechanisms are often used (see, for example, Hofstede, 1991; Inglehart, 2014; Schwartz, 2012; Spony et al., 2014; Trompenaars and Williams, 2003). As a working proposition for this research, national culture is considered as *"the name we give to that which distinguishes the people of one country from those of another*" (Hofstede and Pedersen, 2002 pxviii).

National culture has been identified and explored by researchers including Strodtbeck, (1961); Hofstede, (1991); Schwartz, (1999); Trompenaars and Woolliams, (2003); GLOBE, (2004); Ronald Inglehart, (2014), for half a century. Kluckhohn and Strodtbeck (1961) identify the sub-components of national culture as "value orientations" and identify five possible descriptions and criteria for these value orientations: (1) human nature orientation; (2) man-nature orientation; (3) time orientation; (4) activity orientation; and (5) relational orientation (Kinasevych, 2010 table 1.1). Schwartz identifies ten dimensions as 'common values' which he suggests are universal (Schwartz, 2012). GLOBE acknowledges nine 'cultural dimensions' (Shi & Wang, 2011) identify six "dimensions", similar to those described by Hofstede. To make such intangible characteristics measurable Spony, Trompenaars, Hofstede and others, allocate a numeric value to each cultural dimension. In such a contested area it is unsurprising that social scientists apply different interpretations to the same countries, and that there is no universal or consistent acceptance of any single model.

For the GCC states, Hofstede measured the Kingdom of Saudi Arabia, the Sultanate of Kuwait and the United Arab Emirates (Hofstede, 1991). Trompenaars and GLOBE have both studied the GCC states of Kuwait and Qatar (Baumann, 2013; Shi & Wang, 2011, p. 95). The World Values Survey (WVS), will complete their current cycle of global surveys in 2019, and this will include Saudi Arabia and the U.A.E. The WVS updates their models regularly and map cultural shifts through an interactive map (www.worldvaluessurvey.org).The set of cultural measurements developed by Hofstede cover eighty-five per cent of the GCC population, and this provides the most comprehensive current set of measures available for the GCC, however it must be considered that this research has not been updated in the last three decades.

4.2. Cultural Integration and 'culture shock.'

Lewis (2016, p. 19) describes the individual's experiences of 'culture shock' as an uneasy feeling in which "precious values and unshakeable core beliefs take a battering when we venture abroad". Hofstede describes the process as the visitor in a foreign culture returns to the mental state of an infant, in which the simplest things must be learned over again. This experience usually leads to feelings of distress, helplessness, and hostility toward the new environment (G. Hofstede, Hofstede, & Minkov, 2010). Canadian anthropologist (Oberg, 1960) is generally credited with first describing the concept and coining the term "culture shock", which he describes as the state of anxiety and frustration resulting from the immersion in a culture distinctly different from one's own.

Researchers, in many cases, identify "stages" of culture shock, with the perceived number of stages fluctuating according to the level of detail recognised. Some suggest a six-stage cyclical approach comprising 1. Preliminary →2. Spectator→ 3. Participation 4. → Shock stage 5. → Adjustment and 6. → Re-entry (Moran, Harris and Moran, 2011 p212-216). The Project Management Institute (PMI) recognises nine steps (Kay, 2014- p249). It is common to encounter a four-stage approach (sometimes with an extra step). The extra step is reintegration to one's original culture, or "re-entry stage" (Moran, Harris, & Moran, 2011, p 274). A typical 4 stage approach is shown in Figure 1.

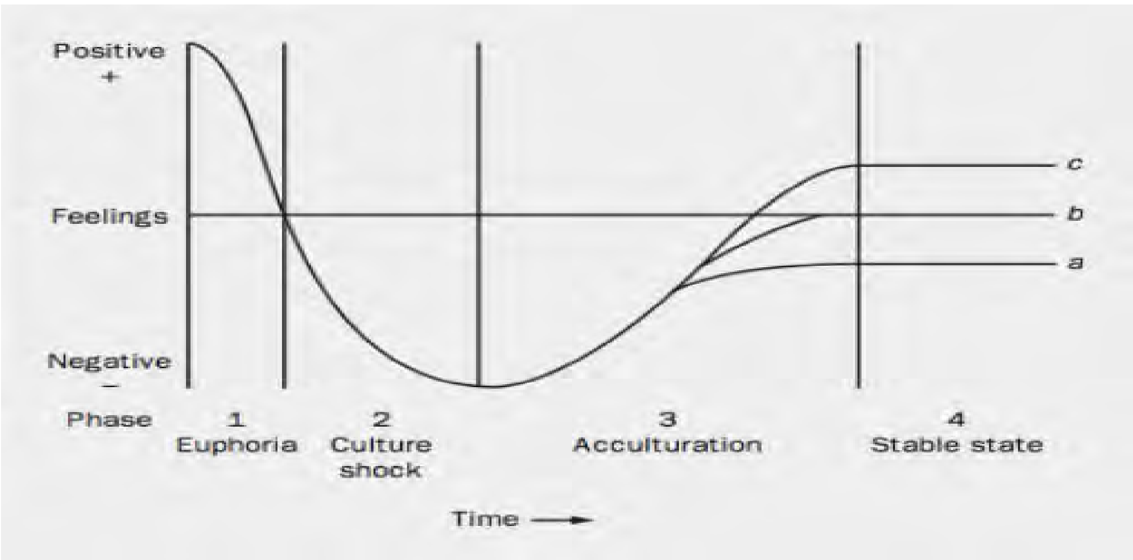

Figure 1. Abstracted from Hofstede's " Exploring Cultures" (Hofstede, 1991a p385)

In Hofstede's portrayal of cultural shock, the first journey is a feeling of euphoria, a honeymoon, filled with the excitement of travelling to a new land; then culture shock occurs when real life starts, and the new environment kicks in. Acculturation follows as the outsider slowly learns to function in the new environment, accepting some of the local values, and integrates (with varying success) into a new social network. Hofstede describes the final integration as a stable state of mind (from Hofstede, 1991a p384-385). It is interesting to note that those interviewed to date as part of this research, perceived that the settling in period - Stages Three and Four (acculturalization and stability) was typically between twelve and eighteen months.

5. Research Methodology

The research described in this paper adopts a two-phase approach: firstly, through literature review and secondly through empirical field research. This approach is shown diagrammatically in Figure 2 below.

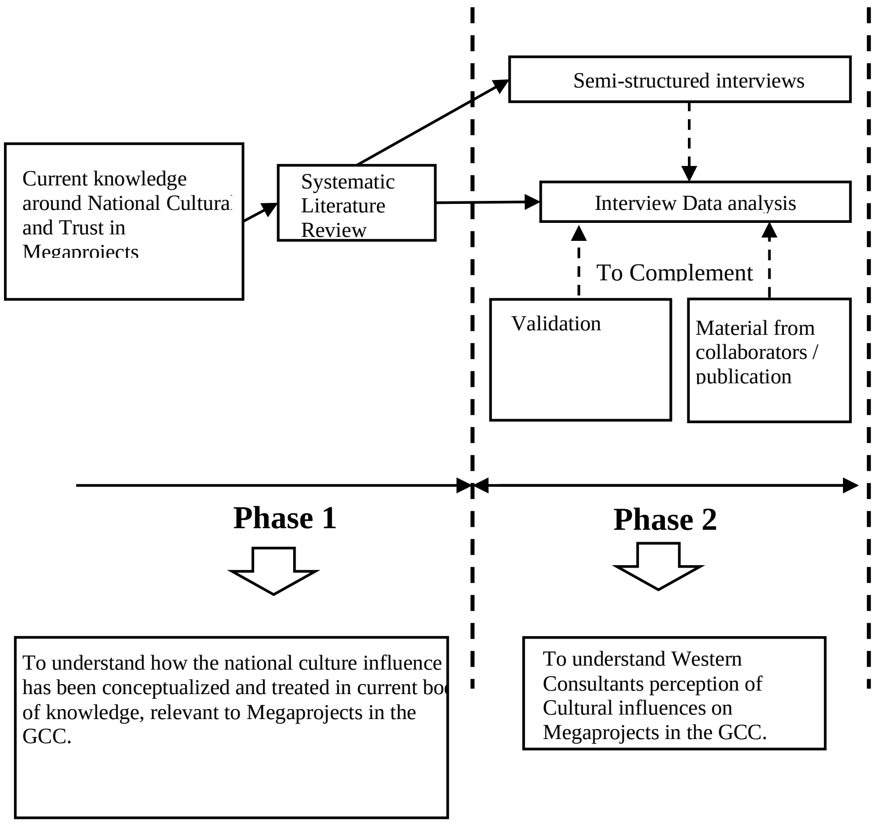

Figure 2. Conceptual representation of the research method adopted from Teo and Loosemore (2014)

Between March 2018 and May 2019, the researcher investigated the contribution of cultural dissonance to churn in a GCC megaproject using a Qatar pilot study. The pilot study specifically explored the substantial churn for individual Western consultants on the megaproject. It examined the reasons for the churn, searching for links to cultural dissonance and used the findings to analyze cultural issues that critically impacted the Western consultancy practice. The pilot case study exposed cultural dissonance as a real and significant phenomenon during the execution of at least one GCC megaproject and identified some specific cultural dissonance sources. It identifies a significant executive churn rate for the megaproject, considering that 28 senior executive positions were approved and that 75 individuals occupied these positions. The factors leading to the churn were investigated, and many natural reasons for departures, such as the project directors decided to leave the GCC, the fulfilment of their role or their retirement were discovered. However, in more than half of the cases (40), it was found that cultural dissonance had played a significant factor in the executives' removal, making cultural dissonance a risk factor during the execution of GCC megaprojects.

This research was then expanded to consider all GCC states and gather data from a broad selection of GCC megaprojects and a full spectrum of Western consultants in various roles. The study purposefully targeted contemporaneous megaprojects as of November 2018. A focus group and prior research helped develop a questioning framework, and interviews progressed until reaching the data saturation point in February 2020. Thirty-four senior project directors participated, and the data were analysed using Grounded Theory techniques. The findings related to the need for a greater cultural awareness are discussed in this paper.

5.1. Literature Review

The extent to which national culture exerts influence on construction projects in the GCC has been explored by many including Harrison and Michailova, (2012) Baumann, (2013) At-Twaijri and Al-Muhaiza, (1996) Newman and Nollen, (2016) Jaeger and Adair, 2013 and Mais Sartari (2010). Haak-Saheem (2016) outlines specific disparities between GCC and western culture. Harrison & Michailova (2012) studied the roles of expatriate females living in the GCC. Baumann (2013) specifically focused on time overruns related to National Culture influences. At-Twaijri and Al-Muhaiza, (1996) studied the GCC’s oil industry, and Sartari (2010) conducted specific research examining one particular group of western consultants. Haak-Saheem (2016) specifically researched the potential introduction of public-private partnerships in the GCC. Al-Hashemi (2016) reviewed the influences of organisational culture on Kuwait’s construction industry. There are also several cross-cultural studies suggesting differing cultural approaches to management within the GCC, such as Bakhtari, (1995); Chapman, (2004); and Jaeger and Adair, (2013).

Outside the GCC there is extensive research on megaprojects (Smits and van Marrewijk, 2014; van Marrewijk, 2007; Van Marrewijk et al., 2014; van Marrewijk et al., 2016) including the Panama Canal extension, the OMEGA megaproject in France (a French high speed rail system), Netlipse (a network associated management of large infrastructure projects in Europe), Nabucco (a 1300 km pipeline through Turkey, Austria, Bulgaria, Romania and Hungary) where researchers have found that culture and trust are critical to the successful completion of megaprojects (Rafindadi et al., 2014; Suprapto et al., 2016; Van Marrewijk et al., 2014). Collectively, such researchers have has identified cultural issues amongst the management team leadership/governance of megaprojects, labelling cultural dissonances as a “significant risk” that requires “special considerations” and management during the lifecycle of the megaproject (Biesenthal et al., 2018; Smits & Brownlow, 2017; van den Ende & van Marrewijk, 2015). Merron, (1988) researched the failure of global megaprojects and concluded that megaprojects are large bundles of risk compounded at every corner, including political, financial, time and culture and strongly recommends that that one considers culture within all future megaprojects (Merron, 1988 p vi). However, little attention has been directed to the impact of culture upon GCC megaprojects, to date. From this literature review, it is evident that there is a current gap in knowledge explicitly relating to GCC research on the influences of culture in megaproject management. The pioneering works of Hofstede et al., (2002) remains crucial to the understanding of national culture. Hofstede has developed "cultural dimensions" that measure power distance; individualism; masculinity; uncertainty avoidance; long term orientation; and indulgence.

Cultural scoring mechanisms indicate the cultural differences between Arab and Western cultures in other dimensions. According to Hofstede, Arab countries have high power distance tendencies where societies have more respect for the position, age, status and rank. Conflict and negative talk are kept private, as raised voices or public humiliation is considered extremely disrespectful. (Power Distance). The GCC is a collectivistic society with a close long-term commitment to the member 'group', be that a family, extended family, or extended relationships. Loyalty and culture are paramount and override most other societal rules and regulations (Individualism). There are family and moral values associated with caring for extended family and caring for others, which may take precedence over the need to be successful (Masculinity). The GCC exhibits a high preference to avoid unpredictability (Uncertainty Avoidance).

5.2. Field Research

This research utilizes the principles of grounded theory as a fruitful way of exploring a substantive area about which little is known (Barrett & Sutrisna, 2009, p. 936) where qualitative studies involving purposeful sampling is engaged until the juncture where data received reached saturation point (Barrett & Sutrisna, 2009; Glaser & Strauss, 1967; Prior, 2008; Saunders et al., 2008). As the research draws on the experience of practising participants, semi-structured interviews are engaged, in preference to structured or in-depth interviews. The semi-structured interviews investigate the viewpoints of western consultants by recording their personal experiences. The results of the interviews were thematically analysed, and the results collated. The credibility of such research is, of course, endangered by the potential of bias. In an effort to mitigate the impacts of researcher bias, findings are triangulated.

5.3. Purposeful selection

Purposeful sampling methods (Hoepfl, 1997; Leedy & Ormrod, 2015) were adopted for this phenomenological inquiry, which seeks to understand cultural influences in GCC megaprojects. Sixteen methods of purposeful sampling ranging from extreme or deviant case sampling to convenience sampling are identified by Patton and others (1990, pp. 169-183) This research focuses on typical case sampling to ensure an adequate breadth of sampling the investigation, once completed, will include participation of 50% of live megaprojects in the GCC, at the time of the survey. Differing timelines may distort the results, so the research was limited to megaprojects which were active in 2018-2020. In-depth first-hand knowledge was provided by director-level participants. This research has shown that GCC construction directors (or equivalent) have a significant span of experience, generally having between five and twenty years of experience in the GCC and occupy the most senior position within their organisation in the GCC. The terms of the contract generally provide that they are the party empowered to endorse or receive formal communications and to manage their internal staffing requirements (FIDIC, 1999).

The directors of the consultancy firms interviewed come from differing professional backgrounds, including architects, cost consultants, project management or claims consultants. After obtaining ethical consent, directors were approached, and the purpose and requirements of the interview were detailed. Following agreement to participate, semi-structured interviews were held typically lasting for between one and two hours per participant. These interviews allowed the researcher to observe the participants reactions to questions, which provided a more in-depth understanding by giving knowledge of the context in which events occurred (Hoepfl, 1997). For higher reliability, meeting minutes were produced, jointly reviewed and confirmed.

5.4. Industry Consultation

In total, 34 project directors, actively engaged in GCC megaprojects throughout all GCC states, were interviewed as part of a series of semi-structured interviews between 2018-2020. The project directors in this study group are located within professional consultancy organisations who, with relatively minor variation, share the following characteristics:

- They are directly interfacing with the Arab project Sponsor, mostly daily and therefore are positioned to provide front line advice to support this research. They have at least seven years of experience managing their respective consultancy roles. They guide their own often extensive teams.
- Socially, they are unique individuals from a broad range of nationalities, many with different languages, religious beliefs, cultural and emotional norms, from each other and from the GCC nationals.
- Professionally, they have diverse expertise, including design management, programme delivery, and financial control, and they provide expert advice based on their specialised training. Typically, this includes formal post-graduate education, and they have ‘career risen’ within their organisation. However, their status and influence are located in and derived from, their project role rather than their position within the firm. They are all members of a recognised professional institution.
- They are part of a temporary project coalition with similar status within the project hierarchy, but are from different design and construction disciplines, and these are the functions they fulfil. Their association with other consultancy practices working for the megaproject is frequently through a collaborative approach, as often, no direct contractual relationship exists between these Western consultants. Contractual authority and control over contractors and processes lies primarily with the Arab Project Sponsor.
- The respondent's functional focus is on project delivery rather than company strategy; their influence and operation are therefore aligned to the project, not the firm.
- They are project directors within their consultancy practices and generally have a high level of professional autonomy. They consult their partners or head offices on a

need’s basis, but generally manage their consultancy scope and daily delivery requirements without reference to any higher authority.

The questions were derived from an extensive literature review, the researcher's professional experience in the GCC (and elsewhere), a research focus group, and insights received from formal cultural training programmes. The interviews were designed and structured to capture the project directors' perspectives on their daily interactions, with a focus on social and professional challenges, cultural adjustment and training related issues. The interviews covered four core thematic categories for further analysis: social, professional, integration and training.

6. Findings

There is a wealth of information published to date concerning cross-cultural research (for example see Hammerich & Lewis, 2013; Hofstede, 2010; M. Javidan, 2009; Moran et al., 2011; Trompenaars, 1993). There is also research specifically focused on international management of projects (see, for example, Archibald, 1991; Minor, 1999; Obikunle, 2002). One objective of this research is to extend and make more useful the knowledge and information available to western consultants relating to cultural issues that typically arise on megaprojects in the GCC.

Additionally, this research aims to contribute to both the body of research associated with megaproject development; and to cross-cultural research in the global multicultural environment. Findings are presented in the form of a narrative with illustrative quotations to enhance the trustworthiness of the adopted methodology. Findings for four aggregate themes are provided as findings 1 to 4. The findings also combine prior research of cross-cultural experts to compare the initial findings of empirical research with existing data. The analysis and inherent reasoning behind each of the propositions is provided and connected to these themes is as follows:

6.1. Finding 1 - Western consultants should be better prepared for social integration

Some cross-cultural commentators advise that ‘when in Rome, you should do as the Romans’ (Hammerich & Lewis, 2013; Meyer, 2014). Others suggest reviewing the countries *cultural mindset* before engagement, through following a framework such as understanding the type of culture, understanding the differences with your own, respecting the differences and enriching yourself through the new (Elena, 2010). National characteristics associated with Arab nations include suggestions that they are family orientated, conservative, religious, and consultative - not individualistic (Bakhtari, 1995; Erin, 2014; Moran et al., 2011). Cultural commentators also warn of the dangers of leaving your home country to escape *back home* issues, such as relationship or career issues (Moran et al., 2011)

For this research, participants were requested to provide their regional ethnic background, from a selection of the Americas / Europe / Asia / Africa & the Middle East / Australia. The respondents are almost equally split between Europe and Africa and the Middle East. In some instances, participants addressed this research based on citizenship they had been granted, as opposed to their place of birth.

Participants from Africa and the Middle East described the least social integration issues as most had prior links to the community. For others, mainly Europeans, social integration was restricted with many stating that they felt significant restrictions compared to those experienced in Europe. The responses of one respondent that the social side “it is not for everyone”, related to facilities being closed at prayer times, particularly at weekends, the need to wear more modest clothing, and the fact that Saudi Arabia was considered very restrictive for females. Most perceived the procedures for getting visas, official permits and any documentation as highly bureaucratic. The most common perceived benefits were related to health and a tax-free lifestyle, although many reported that these benefits, had reduced in recent years. Most participants recommended the lifestyle. All participants recorded that primarily, their social engagement was limited to interactions with other expatriates and not GCC residents.

6.2. Finding 2 - Professional Integration: Western consultants should be advised of the professional differences to be encountered and the need to build trust between the parties

There are some aspects to each profession that cannot carry through all regions, so a healthy dose of particularism is often required (Trompenaars & Woolliams, 2001). From the onset, it is likely that the consultant will become part of a cultural soup, and may benefit from a framework to manage multicultural teams (Zein, 2015; Ochieng & Price, 2009). Cross-cultural commentators advise that nothing happens quickly and trust is paramount (Moran et al., 2011), and that trust is built up in Arab nations based on relationships (Meyer, 2014, p. 171) There are more significant risks associated with cultural miscommunication at professional levels. For example, a severe cultural mistake would be to embarrass one’s host in public, leading to a loss of “face”. Despite suggestions that society has become more tolerant over the years, the concept of face is still prominent within the Middle East and in the Far East (Webb, 2015). One of the easiest ways to cause someone to lose face is to “insult an individual or criticise them in front of others” (Hammerich & Lewis, 2013, p. 222). Hofstede records that sometimes a “loss of face can be felt more painfully than physical mistreatment.”

For differences between professionalism in the home nation compared to the GCC, the profession of the consultant seemed to influence their perception. For example, significant architectural practices indicated that design parameters were similar throughout the world. Likewise, cost consultants advised that their cost reporting and estimating were identical. While the presentation and content remained generally consistent, the parties reported notable differences were related to the highly developed output demanded and to time frames set, which were frequently unrealistic. They elaborated on the time required to build trust between themselves and the project sponsor, which they found more difficult than building similar relationships in their home country. A standard view expressed was that the unrealistic time expectations resulted in extended working hours leading to a poor work/life balance. An early finding of the study is that the respondents found professional integration a lengthy process, often requiring up to eighteen months to feel professionally accepted.

6.3. Findings 3 - Culture Shock: Western consultants should prepare better to reduce the impact of cultural shock

An emerging finding of the research was that there were extensive education and project qualifications, which were a pre-requisite to western consultants’ consideration for engagement on a GCC megaproject. Despite this requirement for prior local knowledge, most respondents were aware of megaprojects from which key personnel had been removed due to cultural differences. Many participants expressed concern about the threat of project removal. Despite assurances of confidentiality, two firm's directors refused to provide an interview due to concerns based on a perceived job endangerment associated with speaking about such events.

Once key project personnel were removed, respondents cited a slowdown in project productivity, an increased perception of job instability, and reduced morale, all because of such removals. One respondent referred to a very high frequency of replacements in three of his recent GCC megaprojects leading him to suggest. 'You're no good unless you have been kicked off at least two projects and it happens every day'. More than half of the respondents believe it was highly dangerous to have of public disagreement with their Arab counterpart, with many considering this as a critical reason for removal from a project. As part of the on-going research, a project-specific case study is being undertaken to provide additional information to explain this phenomenon better.

6.4. Finding 4 - Training: Western Consultants should be offered training before emersion in the GCC

Cross-cultural experts suggest that cross-cultural preparation can offer benefits including less turnover of staff, resulting in reduced 'return costs' and better performances, productivity and profitability (Moran et al., 2011). This research found that over one-third of participants had received some form of educational training or preparations in advance of their assignment in the GCC. This training ranged between a three-day workshop (one instance) to one-to-one counselling for a duration of between two to five hours for three participants. The participants felt that this had been useful, and the respondents who had received training suggested that they had 'fully acclimatised' in twelve months, slightly under the average fourteen-month acclimatisation period described by others. Those that had not received any form of training suggested that such training would be beneficial. In follow-up questioning, over 60% believe that this would be best provided by external consultants. Only one participant expressed the view that you could *not prepare in advance*.

Notwithstanding such variables, this study explicitly addresses current project directors' perceptions, and they firmly believed that the churn of project directors causes megaproject delays of between one and three months. Almost all project directors perceived that churn rates are higher in the GCC than in their home countries, with two project directors suggesting that the high churn levels are a "fact of life in the GCC".

6.5. What Cultural training do Western Construction professionals want?

There are, of course, benefits to working in a multicultural environment. Anthropologists suggest that executives should view a multicultural climate positively, and embrace the culture as a 'strategic asset' (Hofstede Insights, 2018), where all parties gain from combining global experiences (van Marrewijk & Smits, 2016). More than two-thirds of executives consider that they were not prepared for the benefits or challenges associated with entering a new culture. Marquardt and Hovarth (2001) suggest that established multicultural teams outperform mono-cultural teams for a variety of reasons. Team benefits include problem identification and resolution, which are easier to resolve in diverse groups which provide different perspectives on problem-solving.

Wang & Varma (2019) suggest that the cultural distance between countries has a direct relationship to an expatriate's assignment failure. Their study found that that the more similarities that exist between the two countries culture, then the less likely that the assignment will fail.

The surveyed executives were mostly seasoned GCC professionals, actively engaged with GCC megaprojects (the study participants were in the GCC for an average of seven years). They were asked to reflect upon this experience and consider if inter-cultural training (ICT) would add value to the megaproject delivery process. Executives reported that more effort should be extended to help prepare executives for both social and professional challenges. Over ninety per cent of executives believed that ICT would have been of benefit to them or could assist future expatriates, enter the GCC. Elena (2010) has found that intercultural awareness training can assist executives in understanding cultural differences. Baumann (2013) suggests that such training activity is kept simple, uncomplicated and straightforward guidance to help executives achieve cross-cultural teamwork.

Al Mahrouqi (2018) promotes the benefits of ICT in the GCC after studying the rate of senior executives churn in Oman. The study identified how social differences, such as Arabic male cheek to cheek greetings and female's reluctance to make direct eye contact, harmed the executives' integration. Their research also identifies a clear link between an expatriate's premature departure from Oman and the lack of adequate cultural preparation. Their findings strongly advocate that sufficient training and support is provided to support transitioning executives. They specifically recommend that ICT training includes 'awareness and familiarity training' and preferably 'language and communicational training' together with necessary assistance on practical issues, such as housing and schooling for incoming workers. De Vries (2019) found that successful expatriates need to develop a keen awareness or acceptance of their cultural surroundings and develop a sense of 'cultural adaptability' and 'emotional intelligence', in addition to cross-cultural coaching, to enhance their professional integration with the local culture. The executives in this study most recommended the introduction of cultural awareness training and inclusion and diversity training, and a few promoted the benefit of language training, noting however that most construction business contracts were administrated in English.

6.5.1. Inclusion, diversity and cultural awareness training

Ochieng & Price, (2009) suggest that nations have fundamentally differing values, concepts and assumptions. Executives understood the need to identify these cultural characteristics and attributes and exercise a willingness to accept them. Executives referred to fundamental cultural differences between nationalities as well as an awareness of inter-cultural clashes between some ethnicities. Elena, (2010) and Zein, (2015) recommend that inclusion and diversity are better understood by first understanding your own culture and having a willingness to integrate with other cultures. Schein (2004, p.7) recommends that we 'need to see the world through cultural lenses'. Henderson, Stackman, & Lindekilde (2018) finds that cultural intelligence 'directly affecting both performance and satisfaction' in global project teams. Most executives were mindful that a high level of cultural respect must be shown and that the consultant needs to be adept in 'communication, conflict resolution, and team-building'. Al Mazrouei & J. Pech (2014) recommend that cultural conditioning is tailored to the recipient corresponding to the gap between the two national cultures. The executives suggested that ideally, training should specifically be focused to inform executives about cultural norms ‘prevailing in the GCC region’.

6.5.2. Languages and communication training

Executives frequently recommended training in languages or other communication skills. The executives highlighted the importance of the style of communication such as body language and gesture, with executives citing that communication styles were relevant in business dealings and related intercultural negotiation styles, such as how to advise the Sponsor of unrealistic expectations. Some executives discussed emotional intelligence and the need to be culturally intelligent, such as the need to consider one’s audience and the extensive social network between the Arab communities

6.5.3. Other training suggestions

Other recommendations included people acquire more general management training. Struggles & Heidrick (2015) suggest additional skillsets for the GCC should consist of cultural alignment, cultural collaboration, acknowledgement of the soft skills related with personnel, and open cross-cultural communications (Kardes et al. 2013). Some requested ‘Emotional intelligence training’ which comprises a mixture of five skillsets, including self-awareness, self-regulation, motivation, empathy and social skills. Koveshnikov, Wechtler, & Dejoux, (2014), found that high levels of emotional intelligence positively impact expatriates’ cross-cultural adjustment to a new environment that this positivity improves their performance.

6.5.4. Why are these suggestions for training requirements often ignored?

Most executives are not prepared or trained for what to expect in the GCC. The majority recommend intercultural training and proposed additional training to inform them of the cultural challenges they may face. While most consultants were in favour of training, very few executives disagree with its principles. This minority suggested that cultural appreciation could not be taught, as cultural integration **‘**was an integral part of one’s personality’.

Ertek & Tahir (2017) explore reasons why cross-cultural training is frequently not offered, and after meta-analysing research identify common reasons given for the lack of training support including;

1. ICT is not considered financially viable.
2. There is a lack of time before GCC engagement.
3. There is a reluctance due to the temporary nature of overseas postings.
4. There is a lack of ability to conduct cultural awareness training.
5. Training specialists and experts are absent.
6. There is a belief that superior technical abilities are the fundamental pre-requisite for success in the overseas posting (Ethnocentric Behaviors).

There are, of course, frequent instances where the employer may blame assignment failure on the individual consultant. Mercer’s extensive review of international assignment policies and practices attributed 44 % of the blame to poor candidate selection (Mercer, 2015). Despite similar references to ‘weak candidate selection criteria’, KMPG’s 2017 survey of global assignment policies indicates that 89 % of consultants interviewed do not have a formal selection process for international assignees (KPMG International, 2017 p.27).

7. Why cultural harmony is crucial - the cost incurred for high churn

Uncovering specific data for churn is difficult as such data is considered sensitive, and it was challenging to gain access to research that fully triangulates these findings (in the pilot study project directors were subject to an average tenure of nine months). Another relevant data source is a study by Black and Gregersen (1999), who found that churn for expatriate managers can be twice that of home (based on an American study.). There are significant variances in the assessment of the costs with churn. Leiß (2013) suggests costs of $150,000 per early repatriation, while Black and Gregersen (1999) offer higher costs of $1,000,000 per manager (this research considers senior project directors at the equivalent manager grade). Nowak and Linder (2016) provide a framework to assess the expatriate's investment return. It includes charges such as replacement costs, temporarily reduced productivity of the replacement and management costs. The cost centres they identified demonstrate the range of costs that need to be considered when assessing the total costs for churn. The cost centres and charges identified in Nowak and Linder's research (2016) were used as a benchmark to estimate likely GCC costs.

These financial computations support Black and Gregersen (1999) findings that the cost for churn of project directors is in the region of $1,000,000 per project director in GCC megaprojects. However, it is evident that the financial losses related to such calculations do not include the intangible costs associated with the early departure of key personnel. Interviews recorded intangible difficulties faced by the project, including project disruption, lower staff morale, loss of momentum and loss of reputation. Further research and data collection beyond this paper, is required to explain and appreciate the fuller scale of the losses incurred when key people depart the megaproject. These calculations are essential to understand the exposure and risk associated with a Western project director's churn.

7.1. Implementing Cultural Awareness training

Cross-cultural researchers have identified the substantial differences between Western and Arab cultures for decades. They offer their services to ‘decode other cultures to avoid misunderstanding, needless conflict and ultimate failure’ (Myer, 2018, p. 12). There are both organisational levels resources such as the Hofstede Institute (www.hofstede-insights.com) or Trompenaars THT institute (http://www2.thtconsulting.com), and individual experts such as Omar Zein (Zein, 2016a) and Karen Smith (www.crossculturework.com). They aim to assist with analysis, provide bespoke educational training courses or detailed reports outlining the measures necessary to succeed in the Arabic culture. They can provide individual or group specialist advice for the preparation required to acclimatise.

Their recommendations often include cultural alignment, cultural collaboration, acknowledgement of soft skills associated with personnel (Struggles & Heidrick, 2015), and open cross-cultural communications (Kardes et al. 2013). They promote flexibility by first understanding your own culture and having a willingness to integrate with other cultures (Elena, 2010; Zein, 2015). Despite the availability of such professional advisors, those surveyed to date had little to no intercultural training. During semi-structured interviews, participants acknowledge the need for cultural training and most respondents foresee a significant benefit to such training.

8. Conclusions

The value of GCC megaproject is estimated at $279 billion or 19% of GCC GDP (2020), and an estimated 146 western consultants are active in this market. This research has reviewed the potential impact and benefits of cultural awareness training for these Consultants. It is concluded that there is often a lack of trust between the parties. These trust issues can provide a negative effect on the success of GCC megaprojects. As a megaproject team becomes more cohesive with greater cultural unification of the group, then lessons from megaprojects such as the Panama Canal (van Marrewijk et al., 2016) shows that this will result in improved delivery. Given the high value of megaprojects currently underway in the GCC and recognising the high replacement costs of a single principal consultant, such training has the potential to improving project cost efficiency and to enhance project performance.

The findings of the research suggest that there is a high number of Western professional consultancy staff regularly removed and replaced. The study identifies that staff replacements are in some cases, the result of miscommunication, loss of trust between the parties, or a failure to appreciate the cultural differences between the parties. This research revealed a limited number of western consultants in the GCC who were able to successfully navigate these issues s as evidenced by their longevity of project tenure. The initial findings support the idea that cultural integration requires the acquisition of soft management 'people-skills' and *understanding how people tick* (Hillson, 2009). These observations are echoed by specialised recruitment agencies such as Struggles & Heindrick, (2015) who suggest that a critical requirement for placing executives in megaprojects is the need for "directors to learn the soft skills necessary to manage cultural differences".

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Analysing of Overlapping Project Management and Supervision Services in "Agglomeration" Projects in the Republic of Croatia

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Abstract:

The construction sector of the Republic of Croatia was largely influenced by „agglomeration” projects which involve upgrades to water supply and wastewater collection and treatment infrastructure in social agglomerations. Such projects are largely depending on FIDIC „Red“ and „Yellow” book. For implementing such projects, Works - works contracts; Services - contracts for project management services, supervision services and publicity and visibility services; and if necessary Purchase - contracts for the supply of transport and maintenance equipment; are contracted separately. The rights and obligations defined through project management and supervision services partially overlap. Such "overlap" is to some extent acceptable, as the objectives of both services overlap, but the problem arises from insufficiently clear requirements for each service, from the tendering phase to the conclusion of contracts and the establishment of procedures, so there is the possibility of different interpretations of the domain of the Project Manager and the Engineer / Supervisor. Since contracting services for Agglomeration projects is carried out through public procurement, which should allow rational and efficient spending of funds, services - as well as works and procurement, but which are not the subject of this paper - should really be unambiguous and unmistakable in order to acting in accordance with the agreed requirements would be transparent in the domain of action and comprehensive in the domain of services provided to the Client. The primary goal of the service overlap analysis is to provide recommendations for unambiguous and unmistakable descriptions of the scope of project management and supervision services and guidelines for building the relationship between the Project Manager and the Engineer / Supervisor in the optimal development of Agglomeration projects.

Keywords: *project management; supervision; services overlap; agglomeration; construction; project*

1. Introduction

The agglomeration consists of public water supply and public drainage system in one water supply area. Accession Agreement between the Republic of Croatia and the European Union sets transitional periods for harmonization with EU water directives in terms of achieving objectives related to adequate drainage and wastewater treatment in agglomerations with a population equivalent of more than 2.000 PE. There are 260 of them in Croatia.

For the implementation of the entire project of individual Agglomeration, Works are contracted separately through work contracts; Services through contracts for the provision of project management, expert supervision and publicity and visibility services; and, if necessary, Procurement through contracts for the procurement of transport and maintenance equipment. Whereas contracting of services on Agglomeration projects is carried out through public procurement, which should enable rational and efficient spending of funds, services; as well as works and procurements which are not the subject of this paper; should be indeed unambiguous in order to act in accordance with the agreed requirements in a transparent manner in the field of action, and comprehensive in the field of services provided to the Employer.

This paper will identify and explain project management and supervision services in Agglomeration projects through an overview of the essential elements of rights, obligations and responsibilities covered by project management and supervision contracts and suggest improvements in terms of unambiguity in the interpretation of services. These can create certain guidelines for increasing the knowledge fund and contribute to the profession in terms of unambiguous interpretation of a particular service domain and enabling the achievement of particular goals of project management and supervision.

The primary goal of the analysis is to provide recommendations for unambiguous scope descriptions of project management and supervision services and guidelines for building the relationship between the Project Manager and the Engineer/Supervisor in the optimal development of Agglomeration projects. Recommendations and guidelines will emerge from analyzing and comparing the services listed in the available project tasks for project management and supervision of Agglomeration projects in relation to theoretical, practical and legal assumptions. Such research aims at a detailed analysis and comparison of rights and obligations between project management and supervision. The aim of the analysis is reflected on the observed participants - Project Manager, Engineer, Supervision - in terms of a clearer understanding of the rights and obligations and in terms of avoiding the overlapping obligations and eliminating the possibility of different interpretations of the domain of action and responsibility. The benefits for individual participants can be multiple, from a clearer picture of expectations to better opportunities to achieve the particular goals of each of the roles.

This indicates the need for further improvement of similar projects, so the secondary goal of the analysis is to encourage the possibility of further research and analysis of overall status, i.e. for all projects of public contracting authorities that are subject to the Public Procurement Act (Zakon o javnoj nabavi NN 120/2016), and ultimately the adoption of relevant legal changes in order to define in more detail the scope of services necessary for the implementation of public procurement projects.

2. Area/fields of analyses

2.1. General

An agglomeration is an area where the population and economic activities are sufficiently concentrated that municipal wastewater can be collected and discharged to a wastewater treatment plant or to the end point of discharging into a receiver (Croatian Waters company, 2014). Croatia has chosen a concept which implies that the area of one agglomeration is served with one collection system and one wastewater treatment plant. An initial analysis of such areas was carried out in the Implementation Plan of Water Utilities Directives (*Plan provedbe vodno-komunalnih direktiva*, 2010), when 763 agglomerations or drainage systems with one collection system and one treatment plant were identified, of which 294 agglomerations are larger than 2.000 PE. The plan emphasizes that the spatial coverage of agglomerations and their loads in the future will be adjusted to changes in spatial conditions, i.e. changes in the number of users, economic trends, but also financial capacity and standard of living, defining it as a continuous process, an integral part of planning and management, with generally accepted principles of water protection aiming to maximize the effects on water and the environment in a broader sense and with minimal costs in line with the capabilities of users. In 2014. agglomeration data was updated. The update was mostly related to the load change (new census, and more recent and more accurate information on the number of tourists, industry, etc.), and includes updated coverage and amounts of required investments. The total number of agglomerations was then 767 (4 new agglomerations below 2.000 PE were identified), and their number with a load over 2.000 PE was reduced to 281 agglomeration. (Croatian Waters, 2014)

The approach of a two-year cycle of updating information on agglomerations (Croatian Waters, 2021) has been adopted for determining agglomerations in the Republic of Croatia. According to the latest analysis made according to the situation in 2018, there are 747 agglomerations in the Republic of Croatia, of which 260 are agglomerations with a load of more than 2.000 PE and have the obligation to comply with the Wastewater Utility Treatment Directive (Direktiva o pročišćavanju komunalnih otpadnih voda), that is, the construction of an efficient water supply system and a system for drainage and wastewater treatment.

It is not known when a new update will be made in relation to the data of the recent 2021 census.

To implement the entire project of individual agglomeration, one must separately contract Works through work contract, Services through contracts for project management services, supervision and publicity and visibility contracts; and, if necessary, Procurement through contracts for the procurement of transport and maintenance equipment.

The rights and obligations defined through project management and supervision services partially overlap. Such "overlap" is to some extent acceptable, as the objectives of both services partially overlap, but the problem arises in insufficiently clear requirements for a particular service, from the tendering phase to the conclusion of contracts and procedures. This opens the possibility of different interpretations in practice where the domain of action through the project management contract and through the supervision contract aren't clear.

In 2015, when Spatial Planning and Construction Law of Works and Activities became valid (in further text ZPDPUG as in Croatian: *Zakon o poslovima i djelatnostima prostornog uređenja gradnje* NN 78/15, 118/18, 110/19), the contracting of project management services was conditioned for investors liable to public procurement. Thus, the previous scheme of participants in construction (Employer/investor-designer-supervisor-contractor) has expanded to include the term project manager and now the composition is as follows: Employer/investor-project manager-designer-supervisor-contractor. Although the obligation to appoint a project manager has been in force for six years, the Construction Act (*Zakon o gradnji* NN 153/13, 20/17, 39/19, 125/19) still does not define or mention the Project Manager as a participant in the construction, but the provisions of the ZPDPUG are coherent in this part, i.e. they oblige legal entities to comply with them unconditionally. The legal basis has not yet been set to harmonize the approach of contracting authorities, but it is left to them to contract "extended" project management services that overlap with supervision services, and in practice there are problems in interpreting the domain of a particular service. Also project management does not achieve the goals that are by definition essentially set for, but neither those determined by laws and contracts.

Unlike project management, the legal requirements for supervision are covered by the relevant legislation and are not vague.

Since contracting of services on Agglomeration projects is carried out through public procurement, which should enable rational and efficient spending of funds, services (as well as works and procurement which is not the subject of this paper) should be unambiguous in order to complying with the agreed requirements could be transparent, but also comprehensive in the services provided to the Employer.

Related issues, which inevitably need to be mentioned, is the order of contracting services in relation to each other, but also in relation to contracting of works. Namely, it is often the case that project management is contracted only in the construction phase, and in Agglomeration projects this is almost the rule, which disables the full domain of the Project Manager as it is conceived and set in its essence. Thus, project management is reduced to consulting with certain technical and administrative support to the Employers without the possibility of correcting any errors from previous phases of the project. In public procurement processes, there is little possibility of changes in the phases after the tender that would not entail an increase in costs and deadlines, but also certain risks related to compliance with the Employer's obligations under project financing and control agreements.

2.2. Global trends and standards

2.2.1. Project management trends and standards

Projects are present in all areas of human activity (business, culture, sports, politics, army ...), so the world today can be declared as a world of projects. Current trends show that sectors or branches that are not originally project-oriented are increasingly initiating or using projects, so we can talk about "management by projects" instead of "project management" (Radujković, M. et al., 2012). Hvaing it in mind, there is an obvious need to constantly standardize the way projects are managed given their ubiquity. In order to reconcile all the differences of the activities in which the projects take place, the standards are general and applicable to several types of projects and project management. They serve as the backbone of project management methods, and are fine-tuned as needed by the project. On the other hand, the challenge is to apply some of the standards in a meaningful way, i.e. in terms of benefits for the project, and not in terms of complicating and imposing inappropriate procedures.

World best practices and global standards related to project management are:

2.2.1.1. IPMA - ICB/OCB/PEB

The vision of the International Project Management Association (IPMA, based in Switzerland) is "Promoting competencies throughout society to enable a world where all projects succeed". In Croatia, through the non-profit organization IPMA Croatia, trainings and certifications are conducted so that individuals who develop a career in the field of project, program or portfolio management receive formal certification in the areas of "People", "Practice" and "Perspective". The certificate obtained in this way is one of the possible "tickets" to the Project Managers register maintained by the Ministry.

2.2.1.2. PMI – PMBOK

Another internationally recognized project management certification system is the Project Management Institutes' (PMI, USA-based certification system). The standard defined by PMI is PMBOK (Project Management Book of Knoledge®), and in Croatia, through the non-profit organization PMI Croatia, education and certification of experience, knowledge and skills in project management is conducted. The exam is primarily based on knowledge. The certificate obtained in this way ensures the recognition that the person is competent as a Project Manager in accordance with Croatian legislation.

2.2.1.3. PRINCE2

PRINCE2 is a process-oriented project management method that provides an overview of the basic skills required by a project manager. It is a process-based standard, very prescriptive, so it may seem restrictive, and the certification exam itself is knowledge-based. It is not recognized in Croatian regulations, but can be a good guide for project management as it is based on the experience of thousands of projects by project sponsors, project managers, project teams, researchers, teachers, trainers and consultants analyzed in the UK State Trade Office (Office of Government Commerce, OGC).

2.2.1.4. ISO 21500

The standard of the widely known ISO organization initiated by the British Standard Institute (BSI) was created based on many previously issued standards: ANSI, IPMA ICB V3, PRINCE2, DIN & 9901, BS6079-BSISO15188: 2001, ISO 9001 'Quality Management', ISO 10006 'Guidelines for quality management in projects'. It integrates the best ideas of the stated standards. It describes the concept, processes, roles and responsibilities, and since it does not give details or prescribe but leads and provides general frameworks, it is very prosaic and general and can be applied in all sectors and in all projects. ISO 2150 does not carry out individual certifications.

2.2.1.5. PM^2

European PM2 Project Management Methodology or simply PM2 Methodology was developed by the European Commission as the official methodology for project, program and portfolio management. It is a process standard with clear patterns and instructions. It is applicable to all types of projects as it enables efficient project management and delivery of solutions and benefits to organizations and project participants. It finds greater application in simpler projects. It is also based on the operational experience of projects from European institutions and on elements of globally accepted best practices, standards and methodologies of project management. PM^2 is fully supported by a comprehensive training program (including workshops and trainings), online documentation and an active community within the European Commission and a number of associated European institutions.

2.2.2. Supervision trends and standards

Construction supervision, unlike project management, is not subject to global standardization, as the local circumstances are the ones that significantly determine the conditions for performing the supervision role. There are different principles and approaches to looking at the position of supervising engineer, quality / dynamics / money spending controller, quantity surveyor, occupational safety coordinator and other functions that may or may not be identified with the supervisory role.

The legislative framework in Croatia through the Construction Act (*Zakon o gradnji* NN 153/13, 20/17, 39/19, 125/19) and its bylaws regulates the role of supervision in construction projects. In addition to the obligations of supervision arising from the law, it is important through supervision contracts to explain in detail the service that the Employer of the supervision service should and wants to receive from the other party since there are no legal obstacles to contract someother tasks requested by the Employer (Art. 10 para. 1 of the Regulation on the manner of conducting expert supervision of construction, conditions and manner of keeping the construction log and the content of the final report of the supervising engineer (*Pravilnik o načinu provedbe stručnog nadzora građenja, uvjetima i načinu vođenja građevinskog dnevnika te o sadržaju završnog izvješća nadzornog inženjera* NN 131/21)).

2.2.3. Contracting trends and standards

Those standard forms of contracts and tender procedures preferred by institutions that co-finance projects are most often applied to projects in the Republic of Croatia.

There are several different standardized forms of procurement and contracting in the world. Some "publishers" also published standard forms for purchasing and contracting services.

Following international practices and trends, FIDIC (Fédération Internationale des Ingénieurs-Conseils) has developed types of contracts for each recorded case of allocation of responsibilities and risks, and in 1999 published the so-called ***Rainbow suite*** of contracts - Red, Yellow, Silver and Green book. Besides them, currently one can use Gold, Pink and White book.

All of them have basic features of *FIDIC General Terms and Conditions* - balance, wide applicability, simple language, focus on cooperation instead of dispute, designed for an international market framework and oriented towards a clear division of risks between the contracting partners. (Public procurement, n.d.)

Common features of these general conditions are:

- They contain detailed definitions of all essential terms, mutually coherent provisions and consistently treated and carefully regulated essential procedures and procedures
- They prescribe deadlines and methods of correspondence, ie the obligation to address each issue in writing, which significantly distinguishes them from ad hoc prepared contracts
- They are fair and impartial - the risks are shared between the contracting parties in such a way that they are always assigned to the party that can objectively best manage them
- They are comprehensive and flexible - cover a wide range of needs to regulate the contractual relationship and allow additional adjustment through Particular Conditions

FIDIC's contract terms are not applicable in themselves. They are standard templates of the general conditions of the contract, which the Employers adapt to their own needs through Particular Conditions. It is necessary to adjust the general conditions of the contract to the

Croatian legal system, especially its compulsory provisions and accepted business customs and practices. The Particular Conditions are adjusting the General Conditions in terms of terminology, i.e. by entering and clarifying the appropriate terminology and adding specific requirements and circumstances of a particular contract. In this way, possible conceptual and technical shortcomings of the general conditions are eliminated, and success depends on the ability of the compiler (Employer, consultant, etc.), timeliness and order of contracting works and services. (Public procurement, n.d.)

Without exception, the standard form of contract FIDIC is used for contracting works on Agglomeration projects, although there are no official requirements or recommendations on the need to use this form of contract. This form is widely used in Croatia and is used in most public procurement projects.

For the supervision services, Croatian public company Croatian Waters (Hrvatske vode) have prepared templates accordingly, which indicate the parts that need to be changed in relation to a specific agglomeration. (Croatian Waters, 2017). In the realization of the project according to the FIDIC model of the contract, the role of the Engineer appears, whose rights and obligations are regulated by the General and Particular Conditions of Contract. FIDIC's Engineer has a triple role in project implementation - Project Manager, Contract Administrator and Supervising Engineer. For the Agglomeration projects, the services of a FIDIC engineer and expert supervision are procured in one tender, and services of the Project Manager in another. This division of roles needs to be reconciled through the Particular Conditions of the works contract and broken down in detail in the service contracts.

3. Project management service in Agglomeration projects

3.1. Theoretical and legal aspect of project management

In the literature we can find many definitions of project, project manager and project management that differ in eloquence and length of description, but the majority of definitions are as follows.

A project, specifically a construction project, is a unique undertaking limited by deadlines, budget and specifications. A project manager is a person who manages time, budget and specifications to realize project goals and ‘lives’ with the project from start to finish. In other words, he manages the project. The project management activity has developed through practice and is legally regulated. Project management is the application of knowledge, skills, tools and techniques in order to achieve project goals, with restrictions regarding deadlines, costs and quality. It is necessary to manage the project from the beginning throughout its life in order to maintain continuity of care for the project and avoid disruptions.

A construction project is an investment venture of one or more investors that includes certain activities and events from the idea of a future venture to the handover of project results, and by its use the next phase of the project begins, i.e. economic and any other use of construction project results. (Orešković, 2011) The construction (sub)project includes activities on the construction of a building. (Orešković, 2011) Agglomeration projects, in the part in which this paper deals with them, are construction projects since they cover the period of construction of communal infrastructure.

There are different understandings of the concept of project management. Each of the project participants has their own attitude towards project management. Employers expect to achieve their goals, Contractors consider the Project Manager as an additional obstacle in direct communication with the Employer... In general, project participants often do not have a clear vision of the role of Project Manager since all contracts related to the project are regularly concluded with Employers/investors, and are often incomplete in the part of project management.

Continuing on such different understandings, Kerzner interestingly defines project management as the art of creating the illusion that every result is the result of a series of predetermined and deliberate activities, and in fact it was crazy luck. (Kerzner, 2013)

Project management according to Kerzner (2013) and PMBOK guide (PMI, 2013) includes five project phases: Project preparation, Project planning, Project execution, Project monitoring and control and Project Completion, which indicate the need to form a project management team headed by the Project Manager during all the above phases. Given the huge amount of work in project management, it is clear that, despite the definition that the Project Manager is a natural person, it is not possible for one person to have absolutely all competencies at the highest level to manage a project so it is done by a team of capable people each of whom has their own field of activity.

The performance of construction project management activities, in terms of the Spatial Planning and Construction Law of Works and Activities (NN 78/2015, 118/18, 110/19), means the performance of financial, legal and technical consulting services related to design, construction, using and removing buildings. It is the only law in Croatia that regulates the concept of project management and stipulates the contracting the project management services, ie the appointment of a Project Manager for investors obliged to public procurement on projects of total investment value over certain values for certain types of projects (Article 38 (2)) i.e. total investment value more than 10.000.000 kn for infrastructure.

According to this Law, and in accordance with the definitions, the Project Manager is appointed by the investor in order to optimize the use of funds and time and for the legal and quality construction of the building (Article 38 (1)).

Article 33 of this Law defines work included the activity of project management.

According to this Law, the Project Manager is responsible for performing the work to the investor (Article 38, paragraph 3). The Construction Law (NN 153/2013, 20/2017, 39/19, 125/2019) does not know the project manager as a participant in the construction, but given the mandatory provisions of the Spatial Planning and Construction Law of Works and Activities (NN 78/2015, 118/18, 110/19), in public projects he is a real participant in the construction.

Article 37 of the Spatial Planning and Construction Law of Works and Activities (NN 78/2015, 118/2018, 110/2019) prescribes the appropriate level of experience and education and the necessary knowledge in the field of project management required by a natural person to acquire the right to register as a Project Manager and the list is led by the Ministry of Construction. In addition to formal university education with 300 ETCS credits in engineering, the Law states that a project manager has the necessary knowledge in the field of project management if he has internationally recognized certification of project management

(IPMA or PMI) or additional education in architecture, construction, electrical engineering or mechanical engineering with an educational program that includes at least 30 ECTS credits in areas relevant to the management of construction projects.

Although a person must meet the legal requirements and can act as a Project Manager, the project management activity according to legal provisions includes a wide range of services that require extensive knowledge in various fields and it is unrealistic to expect one person to enter independently in providing such a service and in practice a project management team is formed headed by a Project Manager. Team members specialize in individual areas, and each of them is a Project Manager in accordance to the Law.

3.2. Contractual aspect of project management

The project management service is defined in detail with contract amendments regarding legal provisions in order to clearly define all the requirements of the Employer and the obligations of the service provider. Some important relations from such a contract should be included in the investor's contracts with other project participants in order to their acceptance of project manager's role as a person acting on the project to achieve project objectives and monitor the implementation of all separate contracts.

It is crucial for the successful development of the construction project, and thus for the result of the project which is determined by the degree of concurrence of project expectations and project achievements, that the project owner previously and timely unquestionably and unambiguously determine the requirements for implementing engineering consulting services. (Orešković, 2021) All requirements and restrictions must be contained in the terms of reference. (Orešković, 2021) In the implementation of a project, it often happens that stakeholders try to influence changes in the project task. In this situation, the Project Manager should talk carefully with stakeholder representatives and explain to them how the requested changes, if approved, will affect the costs, deadlines and quality of project results. (Bandić & Orešković, 2015)

There are three possible procedures for forming a management implementation team:

- the team is formed by persons from the functional organization of the project owner
- the tasks of the management implementation team, through a contract, are assigned to another entity (legal person)
- the tasks of the management implementation team are partly entrusted to persons from the functional organization, and partly assigned to another entity by contract. (Orešković, 2021)

In Agglomeration projects, option C is the most common, in cases where utility companies have predicted through feasibility studies that part of the project management team will be from the company and part will be outsourced. Such a combination is generally not recommended (Orešković, 2021), but in the case of Agglomeration it is not necessarily bad. Namely, the person from the company should be familiar with the project from its actual beginnings while the external contractor is introduced to the work just before the start of the construction phase, and even later.

In addition to the above, the topic that inevitably needs to be touched upon in considering the contractual aspect of the role of the Project Manager is the order of contracting services in relation to each other, but also in relation to the contracting of works. Namely, in Agglomeration projects, it is often the case that project management is contracted only in the construction phase, which prevents the full domain of the Project Manager's work as it is conceived and set in its essence. Thus, project management is reduced to consulting with certain technical and administrative support to the Employer. In public procurement processes, there is little possibility of changes in the phases after the tender phase that would not entail an increase in costs and deadlines, but also certain risks related to compliance with the Employer's obligations under contract and project financing agreements. Consideration of all the risks that may affect the project is possible if the project is "lived" throughout its life. Thus, we have a case of managing a "subproject", i.e. managing only some of the phases of the project, and we encounter many historical unknowns and project management can only be partially successful.

In addition to the activities that the project management services covers by law, the contractual service is supplemented and detailed with the following appendices:

1. Description of project objectives that are similar, if not the same, in all Agglomeration projects
2. Purpose of project management - to enable timely and effective implementation of the project through certain activities
3. Expected project management results

The contract also regulates possible restrictions in the actions and powers of the project manager, thus most often limiting his independence when deciding on subcontractors, changes, suspensions and continuation of work. The contract defines the deadlines and places of execution of the project management service, the contents provided by each contracting party, the requirements for professional staff, i.e. persons participating in the execution of the contract and the price for the contracted service.

4. Supervision service in Agglomeration projects

4.1. Theoretical and legal aspect of Engineer/supervisor

Unlike project management, the legal provisions for performing professional supervision are covered by the relevant legislation and are not vague, and the theoretical literature does not deal significantly with interpretations of the scope of supervision services. Also, the scope of activities of FIDIC Engineer is discussed at professional seminars and various trainings regarding FIDIC and comes down to interpretations of the General Conditions and recommendations on how to adapt FIDIC to the requirements of certain projects through Particular Conditions.

From the legal aspect, Special Customs on Construction (Posebne uzance o građenju NN 137/2021), Custom 84, states that “The Employer has the right to appoint a person who performs professional supervision to check and ensure proper execution of works, especially regarding the type, quantity and quality of works, materials and equipment.“ The Construction Law (NN 153/2013, 20/2017, 39/2019, 125/2019) which defines the investor who is also the Employer in the Agglomeration projects, states in Article 49, paragraph 3 that Investor is „...obliged to ensure proffesional supervision over construction ... “.

The position of the Engineer is not defined by legal provisions, but is contractually defined if the FIDIC General Conditions of Contract are applied to projects, which is the case with Agglomeration projects.

According to Article 48 of the Construction Law (NN 153/2013, 20/2017, 39/2019, 125/2019), the participants in the construction are the investor, designer, contractor, supervising engineer and auditor. In accordance with other regulations or contractual requirements, some other actual participants are usually added to these formal participants, and in Agglomeration projects these are: Employer, end user, control body, nominated subcontractor, project manager, Engineer, etc.

Article 56, paragraph 1 of the Construction Law defines that "A supervising engineer is a person who, according to a special law, has the right to use the professional title of certified architect or certified engineer and conducts professional construction supervision on behalf of investors."

Article 58 of the Construction Law prescribes the obligations of the Supervising Engineer.

Custom 87 states that "A person performing professional supervision is not authorized to change the technical documentation on the basis of which works are performed, contracted prices or other provisions of the contract, nor to contract other works with the contractor or arrange other property relations with him, unless having a special authorization from the Employer. "

Article 10 of the Regulation on the manner of conducting expert supervision of construction, conditions and manner of keeping the construction log and the content of the final report of the supervising engineer (In further text PoN as in Croatian: Pravilnik o načinu provedbe stručnog nadzora građenja, uvjetima i načinu vođenja građevinskog dnevnika te o sadržaju završnog izvješća nadzornog inženjera NN 131/2021) states that "In addition to the tasks of performing professional supervision, the supervising engineer may also perform other tasks entrusted to him by the investor ...". In the "old" regulation (PoN ..., 2019) in Article 11, these "other" tasks ware partly listed (technical consulting activities, control of fulfillment of contractors obligations torwards the Employer and taking appropriate measures to implement these obligations, calculation of performed works, etc.). The Regulation, ie the Regulations point out to the need for the contract to regulate all activities, which is necessary in practice in order for the parties to be fully aware of what they have contracted. It is necessary to contractually define certain restrictions in the powers of supervision that the investor / Employer considers necessary.

Other technical regulations related to the professional supervision services can be found in the following regulations:

- Construction Products Law (Zakon o građevnim proizvodima, NN 76/13, 30/14, 130/17, 39/19, 118/20)
- Regulation on technical inspection of buildings (Pravilnik o tehničkom pregledu građevine, NN 46/2018, 98/2019)

4.2. Contractual aspect of Engineer/supervisor

For Agglomeration projects, the services of a FIDIC engineer and expert supervision are procured and, following the results of the tender, contracted together. There are different approaches to the requirements for experts who will perform the contracted service of Engineer / Supervisor, so there are examples where the Engineer and the Main Supervising Engineer are the same person, but also those where these two functions are entrusted to two people. It is far more correct to separate these two functions since the supervising engineer (either main or by profession) is a legally conditioned position and should not perform business management activities because he deals primarily with quality, while the Engineer is responsible for administering and ensuring contract implementation so under the economic aspect it's a project management domain.

The FIDIC General Conditions of Contract define an Engineer as “the person appointed by the Employer to act as an Engineer for the purposes of the Contract ...” (Article 1.1.2.4) and “… shall include suitably qualified engineers and other professionals who are competent to carry out these duties.“ (Article 3.1.) and „...may from time to time assign duties and delegate authority to assistants… These assistants may include a resident engineer, and / or independent inspectors appointed to inspect and / or test… Assistants shall be suitably qualified persons, who are competent to carry out these and exercise this authority… ”(Article 3.2).

In cases where the Engineer and the Main Supervising Engineer are the same person, and in order to reconcile the legal provisions for the obligation to appoint a "Supervising Engineer" with the need to hire an Engineer, since the Agglomeration projects are implemented according to the FIDIC contracting model, the scope of services in the consulting contract must be specified through the Particular Conditions of Works Contract so that the provisions of the General Terms and Conditions of the FIDIC Contract are amended accordingly. Also, since in projects of the Agglomeration Engineer / Supervisor must obtain Employer's approval for some authorizations, it is necessary to specify such requirements in the Particular Conditions of Contract (Article 3.1).

The contract defines the deadlines and places of performance of the service, the contents provided by each contracting party, the requirements for professional staff, ie. persons participating in the execution of the contract and the price for the contracted service. In addition to the work that the Engineer has according to the FIDIC terms of the contract and the work that professional construction supervision covers by law, the contractual service is supplemented and detailed as needed.

5. Recommendations and guidelines methodology

The first step in developing the methodology is the collection and study of literature with project management and professional supervision themes, based on which an overview of services from the theoretical, legal and contractual aspects is given. In addition to professional literature, foreign and domestic, on the topic of project management and actions within the Engineers and Supervision, the legislation was consulted as well as publicly available data on tender documents and contracts for the studied services. Such data, ie facts taken from publicly available documents, were processed by methods of analysis and comparison. Project management and supervision services in the implementation of Agglomeration projects were analyzed. The comparison method shows which roles overlap and which are possibly omitted in relation to theoretical and legal assumptions.

The analysis is performed from the legal and theoretical aspect, and to a certain extent also from experiential examples. The concept of role includes obligations and responsibilities in providing a particular service. To analyze the roles following were used:

1. template of procurement documentation for professional construction supervision services in the implementation of EU projects (Hrvatske vode, 2017) and
2. procurement documentation for the project management service for which there were no complaints in the tender procedure: *Project management services - IMPROVEMENT OF DRAINAGE AND WASTEWATER TREATMENT SYSTEMS IN AGGLOMERATIONS UMAG – SAVUDRIJA - NOVIGRAD ISTARSKI* (6. MAJ ODVODNJA d.o.o. for drainage and wastewater treatment, 2018)

Croatian public company Hrvatske vode, who, in Agglomeration projects, are Intermediate Body Level 2 (Posredničko tijeko 2), have prepared a template of procurement documentation for professional construction supervision services in the implementation of EU projects in accordance with the Public Procurement Act (NN 120/2016). The aim of publishing the template of procurement documentation is to prevent and reduce irregularities in the procurement procedures and implementation of EU projects and to avoid financial corrections. (Croatian Waters, 2017) The template was published on June 13, 2017. The publication has a "disclaimer" that the Employers of Supervision Services, regardless of the published template, have full responsibility for conducting public procurement procedures and the use of the template does not exempt them from this responsibility. The template for the project management service has not been prepared, but Employers have used, or use previously correctly written tender documents approved for publication by Croatian Waters and based on such tenders prepared / are preparing procurement documentation for the project management service.

When preparing the procurement documentation, the developer of such documentation receives instructions (through their terms of reference) that *"Procurement documentation should be prepared in accordance with the procedures and templates that will be submitted to the Contractor by the Employer, and the Employer will receive it from Hrvatske vode PT2 and will comply with the provisions of the Croatian Public Procurement Act (NN. 120/2016) and related bylaws."* (ODVODNJA d.o.o. Zadar, 2018)

Documentation on procurement of project management services IMPROVEMENT OF DRAINAGE AND WASTEWATER TREATMENT SYSTEM IN AGLOMERATIONS UMAG - SAVUDRIJA - NOVIGRAD ISTARSKI (6. MAJ ODVODNJA d.o.o. for drainage and wastewater treatment Umag, 2018), chapter Terms of Reference, item 63.4 gives a detailed description of the obligations of the Project Management Service Provider. The term Provider has already been introduced in the process of procuring services due to the fact that the Terms of Reference chapter later forms part of the services contract. Therefore, ie through the contract, the Provider provides consulting, support and project management services to the Employer in the implementation of certain activities which are analyzed in detail from several aspects for the purpose of reaching a conclusion on the overlap of services.

Procurement documentation template for professional construction supervision services in the implementation of EU projects prepared by (Croatian Waters, 2017) in the chapter Detailed description of the Contractor's obligations in items 3.2.1, 3.2.2 and 3.2.3 describes the Service Providers' obligations by phases. The term Provider has already been introduced in the process of procuring services due to the fact that the Terms of Reference chapter, which includes a description of obligations, later forms part of the service contract. Therefore, ie through the contract, the Provider provides construction supervision services through the implementation of the main activities:

1. obligations of the Engineer defined by Conditions of Contract for Plant and Design Build (FIDIC Yellow Book) and Conditions of Contract for Construction (FIDIC Red Book)
2. obligations of supervising engineers as defined by the Construction Law (NN 153/13, 20/17, 39/19, 125/19) and the Spatial Planning and Construction Law on jobs and activities (NN 78/15, 118/18, 110/19)
3. supervision over the preparation of project documentation by the Contractor in contracts that are the subject of supervision services
4. all other obligations defined by this Terms of Reference

These "other obligations" mentioned in items 3.2.1, 3.2.2 and 3.2.3 have been analyzed in detail for the purpose of concluding on the overlap of services.

The role of the Engineer/Supervisor in a certain way, i.e. in one part, is defined through Particular Conditions of Works Contract. This link should be clearly stated in the contract for supervision services in such a way that such provisions are stated in the contract of the supervision service provider, or at least in the way that under "other obligations" it is stated that those obligations of the Engineer / supervision are the onese that farises from Works Contract. In any case, it is necessary to provide the supervision service provider with timely and clear information on all services he is obliged to provide during his engagement. In the observed case, Template, such provisions were included in the description of obligations, but without a logical sequence and with partial repetition of obligations, so that, for example, holding meetings is described in two bulletins and is thus mainly transferred to the contract.

The comparison of project management and supervision services resulted in groups of activities in which overlaps were recorded:

- project documentation made by Contractor
- Contractor's warranties and insurance policies
- cash spending plan
- coordination of participants and works
- communication, documentation and archiving system
- cost control
- safety at work (especially when Coordinator II is not contracted as part of the Engineer / Supervision service)
- project disruptions and taking corrective action
- variations and claims
- reporting to the Employer
- reporting to competent authorities
- organizing, conducting and convening meetings

6. Conclusion

During implementation of one aglomeration project, the project management service and the supervision service are contracted separately. Since all works contracts on Agglomeration projects are made according to the FIDIC contract model, the service of Engineer under FIDIC contract terms is also contracted through the supervision service. Since the FIDIC Engineer can have a triple role in the realization of the project - Project Manager, Contract Administrator and Supervising Engineer, this contracting of Engineer through the supervision service is not the only option. A variant of the Engineer's service in the project management team would also be possible, but also in the role of a project manager, as well as a variant of separate contracting. There are currently no such practical examples in agglomeration projects. In any case, the delimitation of roles needs to be reconciled through the Particular Conditions of the works contract and broken down in detail in the service contracts.

Contracting the services on Agglomeration projects is carried out through public procurement which should enable rational and efficient spending of funds and services should be unambiguous in order to acting in accordance with the contracted requirements is transparent in the field of action and comprehensive in the field of service provided to Employer . The services described in the project tasks of both executors, project management and supervision, partially overlap. Such overlap was observed during my own experience of participating in Agglomeration projects and was the reason for a more detailed analysis through this paper.

The project management and supervision services were analyzed on the basis of sample project tasks, and comments were given from the aspect of the affiliation of a certain task to one of the services. By overlapping the scope of services from the theoretical, legal and contractual aspects, the method of comparison resulted in 12 areas in which services overlap. Several tasks were found that, from the theoretical and legal aspect, could fall into another service. I state that they could, and not that they certainly do, due to the problem of the late introduction of the project management service provider. Namely, in circumstances when the Employers contract a project management service from an external business entity after the supervision service, many tasks from the domain of project management are prescribed in the project tasks of supervision. This does not problematize such tasks covered by the supervision service, since such treatment is legally possible, but the overlap of services with the subsequently contracted project management service where it is not clear then whose obligation it is.

In practice, it happens that Employers, unsure what they really need from the contractor, rewrite all items of the Template (Croatian Waters, 2017) and add some more, mostly the same in meaning, different in sentence structure. This can be avoided by hiring an external consultant, in case the Employer does not have an adequate project management service, who would know how to filter items from the Template and compile a description of obligations that are necessary for that project of the Employer.

Project management is purposeful when it is holistic and when it is implemented from the beginning of project development, when living with the project. It is necessary to appoint a project manager when considering the investment, which derives from both legal assumptions and logic according to world practices. Each subsequent change requires certain adjustments, including the delegation of tasks to other project participants through the range of services being contracted. It must be in the interest of the Employers to cover all their project needs through project management and supervision services, but there is no doubt which of the executors of these services is obliged to provide a particular service and in what way, ie that all obligations are unambiguous. The supervision contract should not define business management activities, since supervision is primarily concerned with quality, while the economic aspect of the project is in the domain of project management. This paper tried to clarify the observed problem of overlapping project management and supervision services and encourage the possibility of further research and analysis of area status for others, ie. in general, all projects of public contracting authorities that are subject to the Public Procurement Act (NN 120/2016), and ultimately the adoption of relevant legal changes in order to define in more detail the scope of services necessary for the implementation of public procurement projects.

Activities that would contribute to such further research are:

- Establishment of a publicly available register of Project Managers at the Ministry of Construction
- Engaging the Project Manager in the project / investment design phase
- Adaptation of FIDIC contract conditions to real needs (laws, practice, requirements)
- Control of the real application of adjusted FIDIC contract conditions
- Consider cases where the FIDIC Engineer is a Project Manager with additional services
- Enable the implementation of professional supervision to the executors of the supervision service without additional obligations from the scope of the Employer's project management

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Determining the Weight of the Engineer's Selection Criteria in FIDIC Contracts using the AHP Method

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Abstract:

The implementation of the entire construction process is a complex task which requires knowledge of the law, the technical conditions for the execution of works and the principles of partnership between the contracting parties. A possible system for the implementation of construction projects is therefor the use of procedures based on the model contract terms developed by the International Federation of Consulting Engineers (FIDIC). A characteristic solution for FIDIC contracts is the introduction of an additional administrative body, the Engineer, who responsible for managing the investment on behalf of the Client. Choosing the Engineer is therefore a key decision for the Client. The use of appropriate price and non-price selection criteria is a major aspect of this process. The aim of this work is to identify important determinants for the choice of the Engineer. The results of these studies may be useful for Clients choosing the Engineer to implement public construction projects in Poland where FIDIC Contracts are often used. For the evaluation, the Analytical Hierarchy Process (AHP) was used as one of the common methods for solving multi-criteria decision problems.

Keywords: *FIDIC; AHP; managing entity; Engineer*

1. Introduction

The correct execution of the complete building process of is a difficult that requires not only knowledge of construction law, but also knowledge of the partnership relationships between the project participants. A possible system for the implementation of construction projects is therefore the use of procedures based on the model contract terms developed by the International Federation of Consulting Engineers (FIDIC). These agreements are known and disseminated throughout the world as examples of good practice, drawn up on the basis of many years of experience [http://www.fidic.org/]. They are famous for the fact that they reasonably maintain balance between the requirements and interests of the parties and, depending on the approved contract model, they fairly distribute risks, threats and responsibility. FIDIC contracts have become standards that are of fundamental importance for construction projects. The terms and conditions for tender procedures set out in FIDIC correspond to the requirements of global financial institutions financing different investment projects. They form the basic models of contracts and general terms that determine the extent of contractual cooperation between all parties [Godwin, 2020].

The versatility of the FIDIC Terms and Conditions is largely the result of long-standing know-how knowledge of the reality of the construction sector and the complex legal and comparative analyses carried out by the developers of these Terms and Conditions. A characteristic feature of contracts concluded under FIDIC rules and conditions is that the agreement specifies only the essential elements of the contract, including the subject matter of the investment, the price and the applicable law [Chen *et al.,* 2018]. The general terms of the contract are contained in the General Conditions. The parties may modify the provisions of the General Conditions at their discretion by deleting, adding or amending individual and selected clauses in order to create so-called Specific Conditions that take precedence over the General Conditions.

It is therefore a common practice when preparing construction contracts ~~is~~ to modify the standard contract forms to reflect the best interests of the given project from the owner's perspective. In this process, clauses that may be beneficial Contractor are often modified or even removed, causing them significant potential risks to the Contractor [Lee *et al.,* 2020]. Since most major construction projects worldwide are based on FIDIC Standard Contract Terms, it is important to know the civil law interpretation of FIDIC rules and the risks involved [Purba and Prastowo, 2020]. The paper [Purba and Prastowo, 2020] shows that, the greatest risk in FIDIC construction contracts is when the construction work is caused due to the complexity of the problems at the time of the construction, whether the dispute, payment or claims of work results. An essential feature of the FIDIC Conditions of Contract tis the practical aspect of dispute resolution, which promotes the principle of out-of-court dispute settlement by Adjudication Boards and later by arbitration tribunals. Above all, however, the contract Engineer's decision-making powers should be used in the first stage of conflict resolution. According to the FIDIC Conditions of Contract, the Engineer is not a party to the agreement signed between the Contractor and the Client. It is therefore not possible to amend this contract or release a party from its obligations.

During the construction investment project preparation, the execution of the works and also over the period of notification of defects, the Engineer, in his role of managing and coordinating the contract acts on behalf of the Client and thus is their authorised representative with a number of powers as well as duties. An important aspect in the selection of the Engineer is therefore to clarify the criteria, including their weights, on the basis of which the competent body is selected to manage the construction process on behalf of the Client [Leśniak, 2020].

The aim of the work is to determine the basic criteria and the importance of selecting a Engineer for public projects. For the evaluation, the Hierarchical Analysis of Decision Problems (AHP) method was used as one of the most popular methods for solving multi-criteria decision problems.

2. The participants of the construction process

The participants of the investment process are entities actively involved in the implementation of the investment or construction works. The participants of a construction process (under Construction Law) in Poland are: the Investor; the Investor's Inspector; the Designer; the Site Manager (usually the Contractor's employees). According to the most popular FIDIC Contracts (Red and Yellow books), the participants of a construction process are: the Client; the Contractor; the Engineer.

The participants representing the Client are: the Investor's Inspector according to Polish law and Engineer according to FIDIC Contracts. The scope of their duties is described in detail in the Polish building law for the inspector and in the FIDIC Conditions of Contract for the Engineer. Both entities are supposed to represent (but not replace) the Client and ensure the correctness of construction. According to Polish law, the inspector's list of responsibilities is shorter than that of the Engineer, according to FIDIC. However, they are usually extended by additional requirements of the ordering parties [Zima and Leśniak, 2013].

2.1 The Investor

The Investor (a Client) is an important player in the construction process. According to the model represented by the Polish building law, they are responsible for organising the entire construction project, including obtaining the building permit, preparing the construction design, taking over the management of the construction, drawing up the health and safety plan, carrying out and approving the construction work and supervising it in the event of a high degree of complexity [Building Law, 1994/2006]. In addition, the Client may appoint the Investor's Inspector and direct the Designer to the exercise of copyright supervision. Investors should have the real and legal means to implement their investments. Investments may be financed from the Investor's own resources or through debt financing in cooperation with other actors such as banks or local authorities.

In addition, the Client can act as a direct Investor, who independently and on his own behalf enters into building agreements and organises the entire construction process. The Investor may also use the services of a so-called replacement Investor, who officially represents the Investor in the respective investment process. This cooperation requires the closure of an investment representative office. However, the Investor is not released from liability for the consequences arising from the obligations of the supervisor.

2.2 The Contractor

Other participants in the investment process are the Contractor and its Subcontractors. As a rule, these are specialised construction companies. The Client should select his Contractors on the basis of the following criteria: experience in the execution of a particular type of work, reliability reputation in the construction industry, timely execution of the work or the company's good condition and financial liquidity.

Contractors who are unable to carry out the work on their own will then hire Subcontractors. The participation of such a company in the construction process results, inter alia, from the specialist character of a certain part of the construction work or from the lack of sufficient material or human resources to meet the work deadline. The general Contractor then has control over the employees of the Subcontractors.

2.3 The Designer

The role of the Designer is performed by a natural person who is obliged to prepare the project documentation in accordance with the applicable technical standards and the law. The close cooperation between the Designer and the Client in the initial phase of the construction project is limited to consultations regarding the constructive, aesthetic, functional and usable characteristics of the project. The Designer makes decisions about the materials used, the execution technology and the finishing.

At the Client's the Designer is obliged to supervise the Client until the completion of the construction project. This monitoring will include checking the conformity of the execution with the design during the construction works and the possible changes in the initial planning assumptions.

2.4 The Investor's Inspector

An Investor's Inspector is a body which may be appointed by the Client on his own authority or which is prescribed in the building permit because of the high complexity of the construction work or the likely impact on the environment. The person acting as the Investor's Inspector must have a building authorisation to supervise the construction work in the relevant field. The main tasks of the investor's inspector according to Polish construction law are:

- representing the Client on the site by checking the conformity of the works with the design or building permit, with the rules and regulations of the building industry,
- quality verification of the works execution and construction materials, including the prevention of the use of defective products not approved for use in construction,
- inspection and acceptance of works that are obscured or disappearing,
- participation in tests and inspections of technical plants, technical plants and chimney pipes,
- preparation and participation in the acceptance of the finished buildings and their handover for use,
- confirmation of the work actually carried out and the rectification of the defects and, at the Client's request, verification of the works invoices.

2.5 The Engineer by FIDIC

The appointment of a professional substitute/representative of the Client, a so-called Engineer, to give instructions to the Contractor on their behalf and to exercise supervision, is a solution to the chosen terms of FIDIC. The Client appoints an Engineer without having to justify his choice. The position of the Engineer usually consists of a specialised contractor, a legal person, and its employees are referred to as trained Engineers and other professionals, in short, they are Engineers [Wysoczański, 2018].

Under the FIDIC Conditions of Contract, the Engineer is obliged to perform his duties on a fiduciary basis towards the Client. They should be objective and act in the best interests of the contract and, in the event of disputes between the Client and the Contractor, they should be obliged to make fair and equitable arrangements. One of the powers of the Engineer is to order Variations and Adjustments in the scope of the contractor's works, usually result from planning errors or the poor definition of the Client's requirements.

The role of the Engineer is related to contract management [Latawiec and Iwanejko, 2010]. The terms of the agreement should clearly define the scope of the Engineer's potential interventions and constitute the basis for ensuring the highest possible level of contract performance. The function of the Engineer is extremely important because it is mainly based on gaining the trust of contracting parties, which has a significant impact on the independence of the Engineer.

3. Materials and Methods

The authors of the paper tried to define the criteria for the selection of the Engineer. The information and criteria were established on the basis of an analysis of the tender documents, the purpose of which was to choose the most advantageous tender as a Contractor under the FIDIC Conditions of Contract for various construction projects. The analysis used the AHP method, a general theory of performance measurement that combines elements of mathematics and psychology [Huang *et al.,* 2015]. The AHP method was developed in the late 1970s / 1980s by Saaty [Saaty, 1998], [Plebankiewicz, 2015]. A detailed description of the theoretical basis of the method can be found in the thesis [Saaty, 1998]. The popularity of this method means that it is often used to solve multi-criteria decision problems

The first step of the analysis should be to build a hierarchical structure of the problem consisting of an overarching objective, criteria and alternative decision-making. The preferences and the importance of the separate decision elements are matched on the basis of an element directly higher up the hierarchy. On this basis, the dominance of one element over the other is determined. Second stage of the analysis: introduction of a relative scale of priorities for the comparison of quantitative and qualitative approaches. This is done by comparing the direct degree of importance and preference of all pairs of decision elements without taking into account physical units. Thanks to these possibilities, AHP analysis is used in both qualitative and quantitative analyses [Darko *et al.,* 2018].

On the basis of the tender documents analysis, the aim of which was to select the best tender as an Engineer, the authors identified the most frequently asked requirements and selection criteria. The main criteria and their frequency are listed in Table 1.

Table 1. Criteria for the Engineer selection

Symbol	Criterion	Frequency of occurrence
K1	Costs	20
K2	Quality	6
K3	Experience	20
K4	Response time	5
K5	Qualified staff	20

Saat's fundamental comparison scale [Prusak and Stefanów, 2014] from Table 2 was used to determine the validity of the criteria.

Table 2. Saaty's 9-point scale of comparisons. Source: [Prusak and Stefanów, 2014]

Scale	Definition	Explanation
1	Equality	Both factors have an equal impact on the achievement of the desired objective.
3	Low or moderate benefit	One element is a little more important than the other
5	Strong advantage	Greater impact of one element on the other
7	Very strong advantage	Very strong effect of one element compared to

		the other
9	Extreme or absolute advantage	The Absolutely Greater Importance of the One Over the Other
2,4,6,8	Intermediate values of the above values	In the absence of an appropriate reference point, intermediate values will be used.

4. Results

The AHP method uses the so-called reversible pair comparison, which allows more accurate results than the direct solution. Assessments of individual criteria according to the Saaty scale were made on the basis of interviews conducted by the authors with 5 experts who acted as the Engineers on contracts implemented according to FIDIC conditions. Based on the assessments made, the authors created Table 3 – a pairwise comparison matrix.

Table 3. Pairwise comparison matrix

Criterion	K1	K2	K3	K4	K5
K1	1	8	2	7	2
K2	0.125	1	0.17	2	0.17
K3	0.5	6	1	6	0.5
K4	0.14	0.5	0.17	1	0.17
K5	0.5	6	2	6	1
Total	2.27	21.5	5.33	22	3.83

Table 4 provides a standardised evaluation matrix.

Table 4. Standardised evaluation matrix.

Criterion	K1	K2	K3	K4	K5	Sum
K1	0.44	0.37	0.375	0.32	0.52	2.03
K2	0.06	0.05	0.03	0.09	0.05	0.28
K3	0.22	0.28	0.19	0.27	0.13	1.09
K4	0.06	0.02	0.03	0.05	0.04	0.21
K5	0.22	0.28	0.375	0.27	0.26	1.41
Total	1	1	1	1	1	

The next step of the analysis was to determine the Consistency Ratio CR, as the correctness factor of the analysis performed. In Table 5, the authors determined the values of the priority vectors and eigenvectors and the Consistency Ratio in accordance with the formula (1) [Prusak and Stefanów, 2014]:

$$CR = 100\% * CI/RI \tag{1}$$

Where:

CR – Consistency Ratio

CI – Consistency Index

RI – Random Index

Table 5. Priority vectors and eigenvectors values

Criterion	Total	Priority vectors	Eigenvectors
K1	2.03	0.41	5.23
K2	0.28	0.05	5.05
K3	1.09	0.22	5.18
K4	0.21	0.04	5.06
K5	1.41	0.28	5.23

In Table 6 the authors compiled λ_{max} (the largest eigenvalue), CI (Consistency Index), RI (Random Index) needed for the CR calculation (Consistency Ratio).

Table 6. Values for λ_{max}, CI, RI and CR

Index	Value
λ_{max}	5.15
CI	0.04
RI	1.11
CR	3%

The analysis and structure carried out is acceptable, confirming the Consistency Ratio of 3%. According to the analysis, K1 criterion – cost, then the qualified staff representing and working with the Engineer, and the experience of the Engineer gained from other similar projects – are the most important criteria. The weights of the criteria are shown in Figure 1.

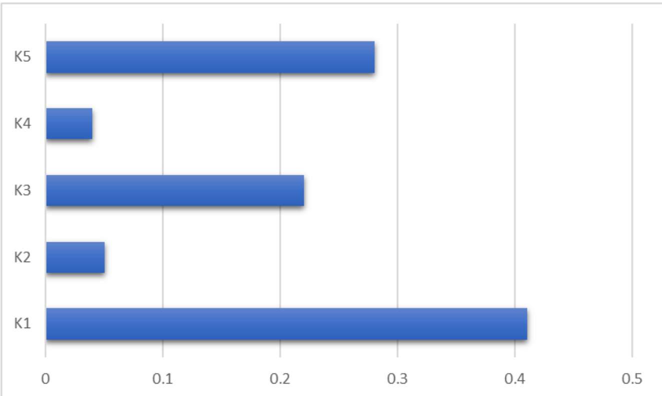

Figure 1. Weights of the Engineer selection criterion

5. Conclusions

Lack of cooperation between the Client and the Contractor often leads to misunderstandings between them and, as a result, to delays in the implementation of construction works and their increased cost. The selection and introduction of the Engineer, who is an independent entity, enables the proper course of the investment and an early detection of disputes between the parties.

The authors of the paper specified the criteria for selecting the Engineer and their weighting. On the basis of the analysis carried out using the AHP method, it was shown that the cost criterion for the service of the Engineer is the feature of the highest importance - 0.41, then qualified personnel cooperating with the Engineer - weight - 0.28, experience of the Engineer in the implementation of similar investment - weight - 0.22. The quality and reaction time criteria had the lowest weight values, 0.05 and 0.04, respectively.

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Using of Modern Technologies in Post-Earthquake Assessments

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Abstract:

Recently, strong earthquakes hit Zagreb, the capital of Croatia and its surrounding area. Croatian building stock is in big part made of masonry. Given that masonry structures are highly vulnerable to seismic actions, severe damage occurred. Especially in older masonry structures built before any enforced seismic codes. Due to widespread damage, there is a great need for a detailed and more comprehensive post-earthquake damage assessment. This field is particularly important for Croatia since the majority of the Zagreb city center is a part of its cultural heritage. This paper briefly presents the post-earthquake damage assessment in the historic parts of Zagreb and the surrounding area after the recent earthquakes in 2020. Also, the role of UAVs, photogrammetry and laser scanners in the assessment and preservation of heritage buildings is shown. Several selected case studies are presented in the paper. Finally, the main advantages of post-earthquake assessment of buildings facilitated by modern technology are discussed.

Keywords: *UAV; laser scanning; photogrammetry; cultural heritage; earthquake*

1. Introduction

In most parts of the European region as well as in Croatia, many existing buildings are built in masonry. The historic urban complex in Zagreb is a protected area regulated by the Law on the Protection and Preservation of Cultural Heritage. Most buildings in the protected area consist of massive longitudinal and orthogonal walls, masonry ceiling vaults, or wooden ceiling beams and wooden roofs. In Lower Town, the buildings are larger by plan than in Upper Town, so the static systems are different. In the Upper Town, family houses and villas predominate, and in the Lower Town, multi-apartment buildings with mostly 7 to 9 residential units are the most common buildings (Stepinac *et al*., 2021). Since most strategic buildings of cultural significance and high historical importance are built using masonry the assessment and rehabilitation of existing masonry structures must be conducted on a very high level (Moretić *et al*., 2022), (Barrile *et al*., 2022), (Hognogi *et al*., 2021), (Stepinac *et al*., 2020), (Ortega *et al*., 2019), (Rodríguez *et al*., 2019), (Stepinac *et al*., 2017). Hence, the regular post-earthquake assessments should be facilitated by state-of-the-art technologies for the preservation and digitalization of cultural heritage buildings. The construction sector is the slowest one to appropriate new technologies and this is something that should be changed (Manyika *et al*., 2017). This motivates the quest for finding the technological solution for the safety assessment of existing structures and the digitalization of cultural heritage buildings (Stepinac and Gašparović, 2020).

2. Recent Earthquakes in Croatia

Croatia is a seismically very active area. Zagreb has a moderate seismic hazard, but it is highly exposed. Awareness of earthquakes is quite limited due to the low frequency of earthquakes. The last devastating earthquake hit Zagreb 130 years ago. Recent two strong earthquakes in 2020 remind us of that. The first occurred in Zagreb in March and was of medium magnitude ML=5.5. The second one had a magnitude ML=6.3 and the epicenter was around 50 km from Zagreb (Stepinac *et al*., 2021). Both earthquakes caused severe damage throughout the city and surrounding areas. Total damage to buildings and other physical assets after earthquakes in 2020. is estimated at 1.38 billion EUR. The damage was mostly concentrated on the buildings in the Lower Town and Upper Town – historical centers of Zagreb, including residential buildings, universities, schools, kindergartens, hospitals and public buildings. Those buildings were damaged because they were built before any seismic regulations. The damage to historical buildings is enormous. Numerous museums, churches, and university buildings have been severely damaged. Most of the damage involved the collapse of chimneys, gables and pediments, attics, prominent cornices and other elements as can be seen in Figure 1.

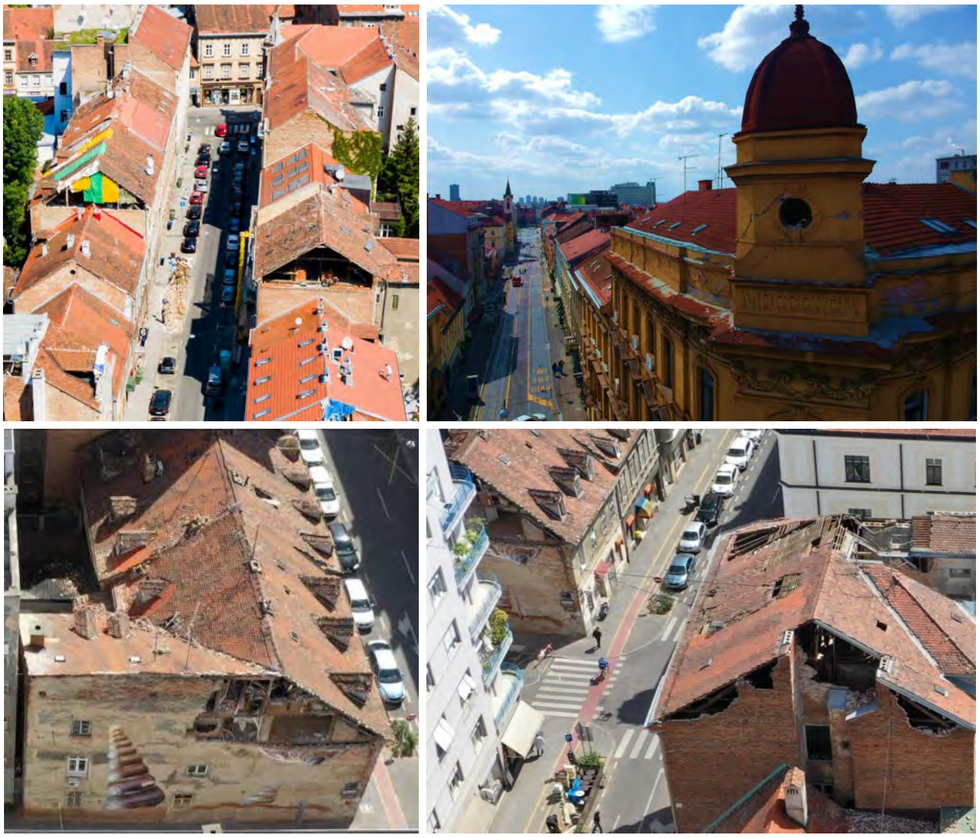

Figure 1. Typical damage after the Zagreb earthquake

In the following chapters, post-earthquake assessment of existing masonry buildings was briefly explained and digitalization of heritage properties is shown in four different case studies.

3. Post-Earthquakes Assessment

A rapid, preliminary assessment of the usability of all buildings damaged in the earthquake was the first step in a complete post-earthquake buildings assessment. Where it's needed, detailed assessment and available Semi-Destructive Testing (SDT) and Non-Destructive Testing (NDT) assessment methods should be applied (Stepinac *et al*., 2020). Generally, the rapid post-earthquake assessment consisted of a rapid visual inspection of individual elements of the load-bearing structure, stating the appropriate degree of damage and the classification of the building into one of six possible categories: U1 Usable without limitations (Green label), U2 Usable with recommendations (Green label), PN1 Temporary unusable - detailed inspection needed (Yellow label), PN2 Temporary unusable – emergency interventions needed (Yellow label), N1 unusable due to external impacts (Red label) and N2 unusable due to damage (Red label). The detailed assessment of the damaged buildings is regulated by the new public law "Law on the Reconstruction of earthquake-damaged Buildings in the City of Zagreb, Krapina-Zagorje County and Zagreb County (NN 102/2020)" according to the procedures in the valid norms, Eurocode norms, and especially EN 1998-3. According to the new law ultimate limit state return period can be different depending on the level of strengthening for old masonry buildings damaged in the recent earthquakes. Usually, the limit state of significant damage with a return period of 475 and limit state of damage limitation with a return period of 95 years have to be checked according to Eurocode 8. In the new law, the return period of 225 years which corresponds to a probability of exceedance of 20 % in 50 years and the return period of 95 years which corresponds to a probability of exceedance of 10 % in 10 years are introduced for a limit state of significant damage. Generally, a detailed assessment consists of a detailed visual inspection of all the structural elements and details, an inspection of structural and non-structural damage, studying archive documentation, on-site and laboratory testing of material properties, and writing a report with described assessment procedures and results. Also, structural and non-structural damage is photographed and described in the report. Often, the MQI method is useful when full NDT measurements should be applied (Borri *et al*., 2015). Through the visual classification of the quality and regularity of the wall elements and mortar joints, an approximate range of values for shear strength, compressive strength and modulus of elasticity of masonry are given. Another NDT method used for testing masonry is the ultrasonic pulse velocity tester. It is based on the speed of the sound wave propagation through the material. As a result, modulus of elasticity is calculated. This method can be used for undamaged and compact masonry elements. Again, from the authors' experience, the results are often unreliable due to the cracked state of the element. Another useful method is the flat-jack method. It is classified as semi-destructive as thin horizontal slots must be cut in masonry to insert thin metal jacks. Hydraulic pressure is applied on the masonry through flat-jacks and by measuring deformations with linear variable differential transformers or portable comparators, insightful material parameters of masonry can be obtained. Such as compressive stress state and modulus of elasticity. With the additional horizontal jack, the initial shear strength of masonry without the influence of vertical stress can be determined as well as the coefficient of friction. Operational modal analysis or OMA also falls in the NDT category. Here natural low-frequency ambiental excitations are used which are then collected through highly sensitive piezoelectric accelerometers. After data processing, final results are presented in the form of mode shapes of vibrations of a building with its natural periods and accompanying percentage of relative damping for each mode shape. Regarding analysis methods, Eurocode 8 offers various linear and non-linear seismic analyses. Still, for existing structures, non-linear static (pushover) analysis is recommended. For existing structures, knowledge levels about their details, material properties and geometry are important as they define allowable seismic analysis and appropriate values of confidence factors. There are three levels of knowledge: KL1 (limited knowledge), KL2 (normal knowledge) and KL3 (full knowledge). All three knowledge levels have their associated confidence factors, which are 1.35 for KL1, 1.2 for KL2 and 1.0 for KL3. Confidence factors are used to determine the design values of the material properties of an existing building. Mean values of material properties obtained from in-situ tests are divided with an appropriate confidence factor. Reduced material properties are then used in the capacity analysis of the building. Afterward, safety verifications are conducted where capacity obtained through pushover analysis is compared with appropriate seismic demand. Geotechnical tests are often not performed. Usually, they are based on empirical data and a category B foundation soil (deposits of very compacted sand, gravel, or hard clay, at least several tens of meters deep) or category C (deep deposits of compacted or medium-compacted sand, gravel, or hard clay with a thickness of several tens of meters to several hundred meters) can be assumed for the most parts of Zagreb. Additional to the "traditional" inspection, the damaged building should be inspected from the air by an unmanned aerial vehicle (UAV) because that way damage can be observed to the main load-bearing structure and the building's roof structure. Decorative crosses, statues and reliefs must also be inspected. With the aim of digital preservation, the 3D model of buildings can be made based on photogrammetric images. Parallel to UAV imaging, laser scanning can be extremely useful for thorough interior inspection, especially when the building in question has a complex geometry and parts hard to reach. Through laser scanning, load-bearing structure geometry and damage can be detected with high accuracy (Parfenov *et al.*, 2022). Investigative work on the existing building should be followed by a static pushover analysis (Pojatina *et al.*, 2021). In Croatia, the most often used software are 3Muri, Scia Engineer and Tower. Unfortunately, non-linear static analyses are not very often used. Following the performed analyses, the real damage can be compared with the damage distribution previewed in software (Lulić *et al.*, 2021). Assessment of a building's capacity through displacement rather than forces allows better understanding and accurately predict buildings response in the form of damage initiation and propagation throughout all phases of analysis until the formation of failure mechanism and collapse (Perić and Matorić, 2020). Finally, the usability of the building is evaluated and methods for the retrofit are given.

4. Selected Case Studies

The focus of this paper is on buildings under heritage protection in the city center of Zagreb and the surrounding area damaged in the recent earthquakes. Case studies are shortly presented with a description, visualized with a photo and/or 3D model obtained by UAV photogrammetry or laser scanning. The post-earthquake assessment was briefly explained and the digitalization of heritage properties is shown in four different case studies. The main focus is set on unmanned aerial vehicles (UAVs) and supporting equipment, as well as photogrammetry and laser scanning. The advantages and disadvantages of the new technologies which should complement traditional methods are given in (Stepinac and Gašparović, 2020). In order to create a 3D point cloud of the building's interior and exterior, the building was scanned with a laser scanner. Leica BLK360 is the laser scanner used in the case studies given below. It is a compact imaging laser scanner that uses a 360° laser distance meter and high-definition panoramic imaging. Then, the collected data is processed in the

Cyclone Register 360 software package. 3D point clouds are delivered with millimeter accuracy with the help of three spherical, panoramic HDR cameras with a thermal imaging camera. The point cloud can further be used to make an accurate 3D model, create a precise 2D floorplan, or convert it into a mesh for visualization. Every case study was filmed from the air and a digital copy of the outer façade was made.

4.1. Case study 1

The building (Figure 2) has a residential purpose and it is located in an area that is under cultural protection. It is made of unreinforced masonry with wall thicknesses from 60 to 45 cm. Floor structures and roofs are made of timber. In rapid assessment, it was classified as temporarily unusable due to the damage suffered.

Figure 2. Aerial photo and point cloud

4.2. Case study 2

This adjacent building (Figure 3) is located in Zone B of Zagreb's historic urban complex. Originally the two-story building was built in 1896. and upgraded to a three-story building in 1938. reconstruction. It consists of the basement, ground floor, first floor and attic. It is a residential building with a rectangular ground plan in the north-south direction. The building's external dimensions are 14,3 x 12 m with massive longitudinal walls, masonry ceiling vaults in the basement, wooden ceiling beams and a wooden roof.

Figure 3. Aerial photo and point cloud section

4.3. *Case study 3*

This case study (Figure 4) is located in Upper Town, a part of Zone A of Zagreb's historic urban complex. It is a residential building with a rectangular ground plan attached to a symmetrically identical building. It consists of the basement, ground floor, first floor and attic. The building was built in 1932. while its original plan was never completed and part of the building was never built. It is a square-shaped building with a masonry construction with timber floors and a timber roof. The building was regularly maintained and suffered minor local damages in the latest earthquake

Figure 4. Aerial photo, point cloud and 3D model

4.4. *Case study 4*

The building (Figure 5) is located in Zagreb and was built in 1974. It is an office building and consists of 3 separate dilatations. The building has an irregular floor plan and has a total area of 2500 m2. The structural system is a combination of reinforced concrete frames and reinforced concrete walls. The roof is a steel structure, and the facade is made of glass.

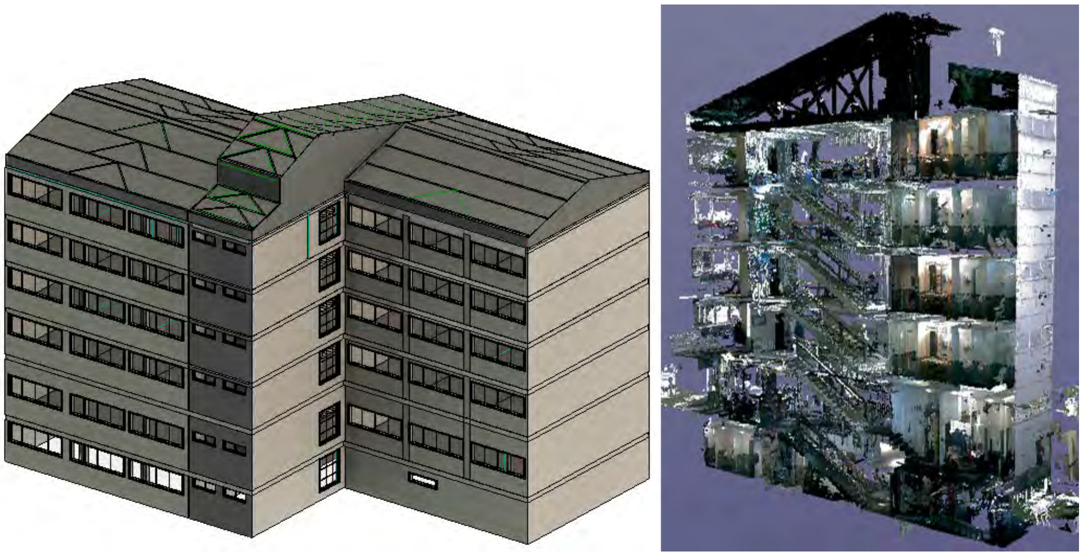

Figure 5. 3D model and point cloud section

4.5. *Flat-jack test*

The laser scanner also has a useful function when testing masonry with the flat-jack method (Figure 6). After making an opening in the wall for a flat-jack it is necessary to measure the area of the opening as it affects the results. Therefore, laser scanning not only speeds up and facilitates testing but also increases the accuracy of the results.

Figure 6. Laser scanner and point cloud

5. Conclusions

In this paper, the "regular" post-earthquake assessment procedures of damaged buildings are given and new technologies such as photogrammetry, laser scanning and UAV are shown in order to preserve the built heritage. Earthquakes caused severe damage, significant financial loss and revealed many flaws in the built heritage that needs to be faced by the combined forces of the public, professional and scientific community. Older masonry structures built before any enforced seismic codes are damaged extensively by the earthquake. Hence, most of the damage was observed in the historic part of the city center. A big part of the Zagreb city center is under some level of cultural heritage protection and therefore, is the most recognizable part of the city as it gives it its identity. The general conclusions regarding the analyzed part of the city are that the damaged buildings are close to the end of their service lives and are built before the implementation of the seismic codes. The paper analyzes the preliminary data of the usability of the buildings in the heritage-protected areas by field engineers and is supplemented with the four case studies where, in addition to regular post-earthquake assessment, point clouds and digital twins of the protected buildings are shown. The basic idea was to show the procedures and possibilities for the preservation of cultural heritage buildings with state-of-the-art technology. The case study buildings should represent a good starting point for further analysis and as a digital twin for different types of users in the renovation process. The knowledge of build back better is fully appreciated, especially after recent earthquakes. Sustainable materials and innovative concepts (Fortunato *et al*., 2017), (Funari *et al*., 2021), (Funari *et al*., 2020), (Kišiček *et al*., 2020) should be used and energy efficiency ensured (Milovanović *et al*., 2020), (Valluzzi *et al*., 2021) along with the seismic strengthening. Preservation through new technologies should be included in the whole process. A compilation of all the assessment data can and should be obtained to get a unique view of the seismic vulnerability of existing structures and not only to the architectural preservation of the built heritage.

Acknowledgments

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Data Management for the Semi-automated Generation of Target/Actual Schedule Comparisons

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Abstract:

There are numerous construction projects that are not realized within the originally planned time frame. Particularly in case of larger and more complex projects it is essential for the contractor and the client to monitor the construction progress regularly by comparing the target with the actual schedule (e. g. in the form of Gantt charts) in order to identify deviations at an early stage. Only when deviations are identified, potential countermeasures may be implemented and reliable schedule forecasts could be made. Creating a target/actual schedule comparison is usually a tedious manual task, which can be semi-automated, if reliable construction site information is provided in form of well managed digital data. It is shown that the required data management can be approached systematically. For this reason, along with a data management concept for the semi-automated generation of a target/actual schedule comparison, 16 related key challenges are considered. Additionally, potential coping measures for these challenges are provided. The outcome is based on the experience gained by the authors through the practical implementation of such a data management in various large-scale projects as well as a literature review. A semi-automated target/actual schedule comparison is advantageous, because it could be generated quickly and cost-effectively in real time based on well prepared and managed construction site data.

Keywords: *data management; target/actual schedule comparison; semi-automated actual schedule*

1. Introduction

There are numerous construction projects that are not realized within the originally planned time frame. In addition to high cost and time pressure during construction, changes and constraints often occur which alter the situation on the construction site and consequently render the planned construction schedule obsolete (Ailland and Bargstädt, 2008). From the contractor's point of view the reasons for this situation can be internal (e.g. lack of materials, staff shortages) or external (e.g. change requests from the client) (Wang and Wu, 2020). On the construction site these changed situations are often met with improvisation, which may have a negative impact on the costs, deadlines and qualities of the construction project (Goger *et al.*, 2018). In order to counteract this negative deviation from the project goals, appropriate schedule control is mandatory. Schedule control includes the determination of target and actual data, the creation of a target/actual comparison and the derivation of control measures (Ailland and Bargstädt, 2008).

Appropriate planning and control of the construction project has a direct impact on the success of the project (Chevallier and Russell, 1998). It is therefore important to obtain a comprehensive and appropriately detailed overview of the construction progress as well as determine any discrepancies with the planned progress at an early stage. The earlier discrepancies are identified, the less likely they are to interfere with the rest of the construction process, as long as decisions are made promptly about potential countermeasures, such as increasing staff or using more powerful equipment. Visualizations can be used e.g. in decision-making (Goger *et al.*, 2018) or the claim management process. This includes common forms of schedule presentation, e.g. Gantt charts or time-location charts. Usually, schedules are created manually, which takes up a lot of time (Kim *et al.*, 2013) and may be prone to errors (Chevallier and Russell, 1998).

As a result of technological progress new opportunities have emerged in terms of optimizing the scheduling process (Kim *et al.*, 2013). With the help of digital solutions, the creation of schedules can be automated to a certain extent. This can lead to more up-to-date schedules, time savings in schedule creation and an increase in operational efficiency (Goger *et al.*, 2018). The basis for this automation process is construction site information in the form of data.

Proper processing and analysis (Taleb *et al.*, 2018) of data makes it possible to obtain information about the situation (on the construction site) and to react promptly to changes (Chen *et al.*, 2013). Furthermore, the information obtained can be used to carry out trend analyses (Möhring *et al.*, 2015) (determination of productivity losses or increases) and forecasts (Wang and Wu, 2020).

For these use cases it is crucial to collect meaningful and reliable information that depicts the actual state of the construction site with sufficient accuracy (Ailland and Bargstädt, 2008). Sound conclusions can only be drawn if the construction progress can be recreated reliably. Collecting reliable information requires a systematic approach to handle data: a reliable construction data management is needed.

It should be noted that neither construction companies (Harkonen *et al.*, 2019) nor client-side project management usually have adequate data management. Although there is a strong correlation between effective data management and economic success, most companies hardly use the data they have (Economist, 2011). Since neither small nor large companies use data as a tool to increase productivity (Harkonen *et al.*, 2019), the potential of these data is often not exploited.

2. Methodology

Two research methods are used for this paper. On one hand, the authors' experience gained as a result of working on several complex projects is incorporated into the paper. The authors have semi-automatically generated schedules from construction site data for railroad, bridge and above-ground construction projects using software solutions they mainly developed themselves. The insights gained and challenges encountered in these projects are included in the following chapters. On the other hand, a literature review is used to establish the basics on the topics of data and data management. In particular, literature on the topic of big data is used, since a large number of premises and process steps can be adapted.

3. Scheduling

For visualizing a construction process common forms of schedule presentation such as Gantt charts, time-location charts or 4D models can be used. Regardless of their structural and visual different setups, all forms of presentation have the elementary commonality that they are based on information tuples (task, object and time vector). The task describes the activity to be performed in relation to the object, e.g. rebar installation. The object refers to a clearly determined component, e.g. foundation axis 10. The time vector consists of a starting time and a duration.

For a semi-automatic actual schedule generation, these information tuples have to be extracted from the existing construction site data. Within Figure 1, an exemplary situation (the construction of bridge columns) is depicted with three different forms of schedule presentation. The snapshot of the 4D model corresponds to the construction progress at the time of the red lines in the other two schedules (see Figure 1). A single snapshot of the 4D model has only limited informative value. It can only be used to visualize deviations of the actual from the target construction state at the time of observation. Contrary to other forms of schedule presentation, progress cannot be displayed within a single image, but only within a movie.

The actual construction sequence shown in Figure 1 is a typical pattern that can be found in more complex projects in construction practice. In addition to a large number of activities taking place in parallel, the start of execution is often postponed and/or the execution period of individual activities is extended for reasons that can be attributed to the client, contractor or force majeure. Furthermore, gaps occur between successive activities or interruptions within individual activities. Among other things, these circumstances make it difficult to create a reliable schedule forecast.

By using programming languages (e.g. C#, java or VBA) schedule files can be filled with the extracted information tuples via interfaces set up by the software manufacturers (e.g. Office.Interop for MSProject) or directly at file level (e.g. XML). These approaches differ in essential aspects, such as functionality, performance and complexity.

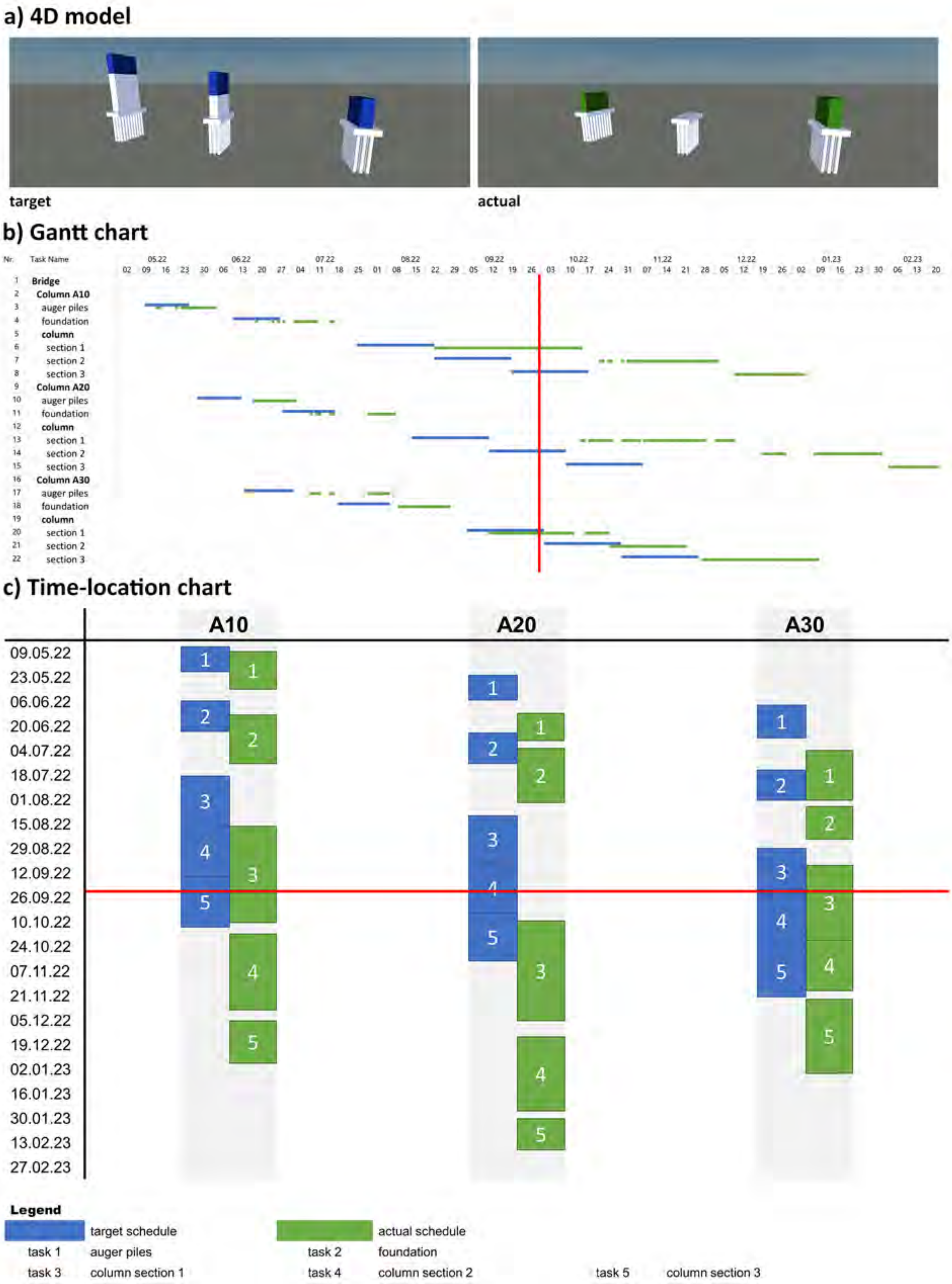

Figure 1. Three forms of schedule presentation for the construction of bridge columns

4. Data

Data are defined as a “reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing” (ISO/IEC, 1993). Consequently, data must be interpreted in order to gain knowledge about the information.

Data exist in a large number of different types and formats and originate from a wide variety of data sources (Taleb *et al.*, 2018). A data source is a functional unit that provides data for transmission (ISO/IEC, 1995), until either a saturation of the data demand has occurred or money/time for data collection have run out (Kaisler *et al.*, 2013).

The amount of data collected shows a remarkable growth rate (Kaisler *et al.*, 2013). This can be attributed to two reasons. On one hand, the number of available data sources has grown exponentially in recent years (Raptis *et al.*, 2019). On the other hand, existing data sources, such as mobile devices or sensors, are increasingly collecting data (Chen and Zhang, 2014). The size of the data collected depends on the respective data source and can be divided into three categories: small (e.g. sensor measurements), medium (e.g. photos) and big (e.g. videos) (Raptis *et al.*, 2019).

Data are distinguished between structured and unstructured data. Semi-structured data (e.g. Chen *et al.*, 2013) are often added to the distinction. However, they are only a subtype of structured data, which is why they will not be mentioned below.

All data that are subject to an enforced structure are referred to as structured data (Weglarz, 2004). In contrast, data that are not subject to a defined schema, rules, or restrictions on creation are referred to as unstructured (Taleb *et al.*, 2018). Unstructured data are divided into two subcategories: bitmap objects (e.g. photos, videos) and textual objects (Weglarz, 2004). In contrast to structured data, unstructured data are more difficult to process (Möhring *et al.*, 2015). This is due, among other things, to the semantic heterogeneity of these data (Doan *et al.*, 2009). For this reason, these data cannot be analyzed directly, but must be processed in terms of content beforehand (BITKOM, 2012). The amount of unstructured data is growing faster than the structured data (Taleb *et al.*, 2018). Most of the data available in companies can be classified as unstructured (BITKOM, 2012). The most important data sources within enterprises produce unstructured data (Kiefer, 2016). These unstructured data include text documents, reports and emails (Weglarz, 2004; Doan *et al.*, 2009; Taleb *et al.*, 2018). Most data collected in the construction industry can be classified as unstructured.

In addition to a growth in volume, the complexity and variety of data are increasing as well (Almeida and Calistru, 2013). Volume and Variety correspond to two of the three Vs of Big Data. The 3Vs of Big Data (Volume, Velocity, Variety) are essential characteristics that set Big Data apart from conventional technologies (Chen *et al.*, 2013). Big Data can be summarized as the utilization of large volumes of data from a wide variety of data sources at a high processing speed with the purpose of generating economic value (BITKOM, 2012).

However, the approach of generating economic value from data has not just been around since Big Data. Companies have been analyzing data (albeit non-digital data) for centuries to potentially improve operational efficiency and gain a competitive advantage (Economist, 2011). Big Data merely provide an alternative approach to analysis (Koseleva and Ropaite, 2017).

This approach shows great potential, especially with regard to otherwise unconsidered data. Unconsidered data are generated at a high cost, but not used (Chen and Zhang, 2014). This includes documents that are created primarily for the purpose of fulfilling a documentation obligation, such as daily construction reports as well as delivery bills. Normally, an analysis of these documents is not provided. However, information could be obtained from these documents and used for production control (on the construction site) (Han and Kamber, 2006).

Although most use cases in the construction industry are still far from Big Data, this topic is becoming increasingly relevant (Goger *et al.*, 2018). Big Data do not add value to smaller data sets that can be processed with conventional methods (Goger *et al.*, 2018). However, Big Data do not emerge suddenly, but are obtained over time from data sources (Almeida and Calistru, 2013). In the long run it makes sense to align strategies related to data management with Big Data approaches, due to the exponential growth in the number of data sources as well as an increasing complexity related to the analysis of the generated data. An abrupt switch to Big Data is not necessary. Existing technologies allow a gradual transition as well as the integration of Big Data techniques (BITKOM, 2012).

5. Data Management

Data management is defined as "functions that provide access to data, perform or monitor the storage of data, and control input-output operations" (ISO/IEC, 1993). In a broader sense, data management is a holistic process from data collection through data processing to the output of results.

Data only offer added value when information can be obtained using analytical methods (Kaisler *et al.*, 2013). However, the information obtained (e.g. on day x, activity y was performed on component z) offers little added value in its pure form. It is crucial to further process the information in order to derive knowledge.

Therefore, *Han and Kamber* have designed a seven-step process of how to extract knowledge from data. This process consists of the steps data cleaning, data integration, data selection, data transformation, data mining, pattern evaluation and knowledge presentation (Han and Kamber, 2006).

However, the mere acquisition of knowledge is not sufficient in most cases with regard to construction processes. For example, a site manager does not only need to know that the planned duration for the construction of a concrete wall has already been exceeded. It is also relevant what effects this will have on the further construction process and what countermeasures could be initiated. What is needed is a series of process steps that enable decisions to be made on the basis of data, thereby creating added value: a value chain.

In order to achieve a data-based value chain, the authors of this paper designed a twelve-step process divided into four phases (see Figure 2) based on the concept for knowledge extraction by *Han and Kamber*, which will be referred to as data management for the semi-automatic generation of target/actual schedule comparisons. Semi-automatic means that manual intervention is required at several points in the process, but the steps, e.g. mining data, are mainly automated. The individual process steps proceed in the chronological order discussed below:

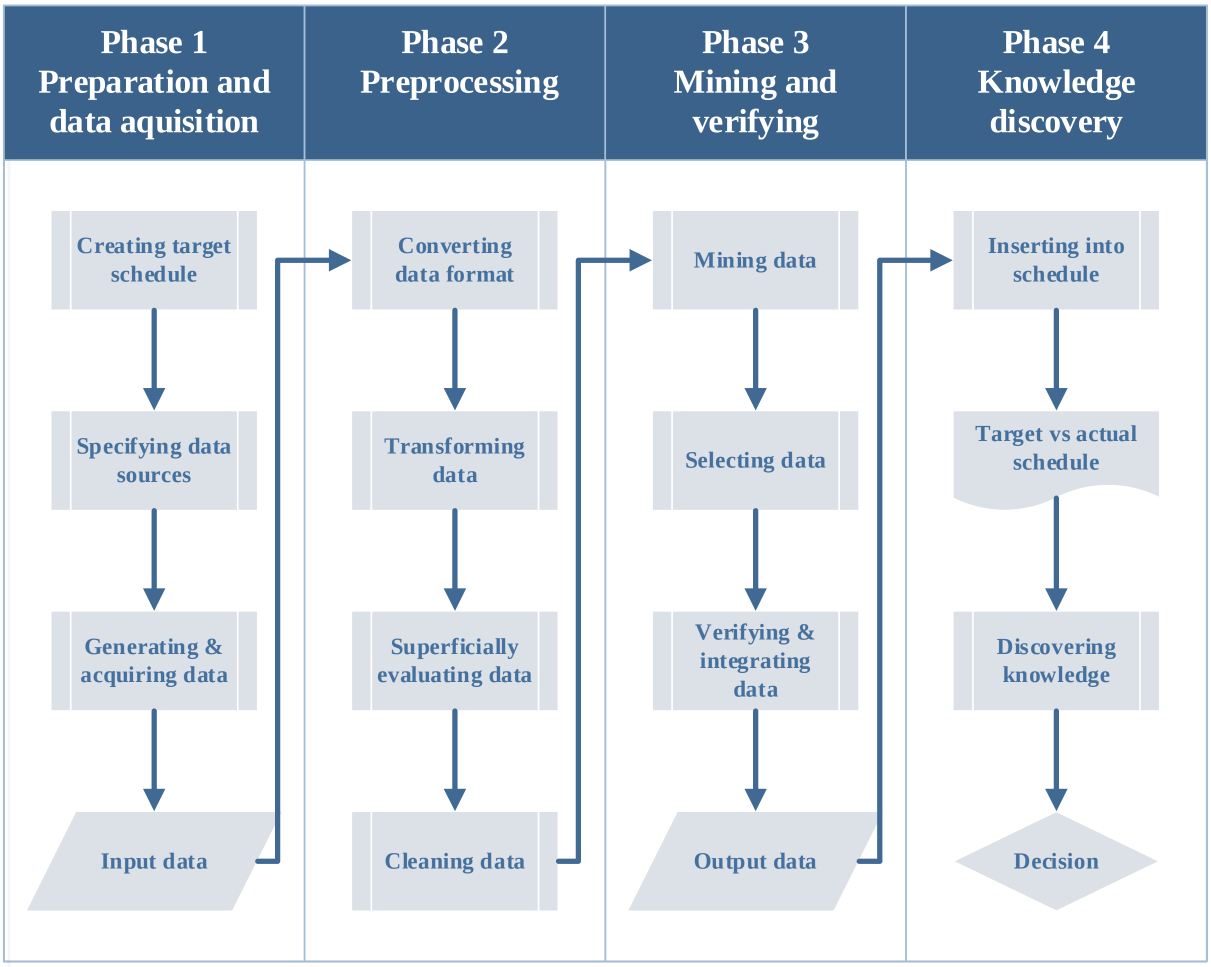

Figure 2. Data management for the semi-automatic generation of target/actual schedule comparisons

5.1. Step 1 – Creating target schedule

In this step the target schedule is created, which will later be inserted with an actual timeline and used for the target/actual schedule comparison. As mentioned at the beginning, this schedule can be available in various forms of schedule presentation (e.g. Gantt chart) and can be linked to a 3D model for the purpose of a 4D visualization. In terms of data management, this further differentiation is irrelevant, since all forms of schedule presentation are based on information tuples. Due to the broad definition of data management, the creation of the schedule, as a prerequisite for the output of analysis results, is considered a first process step.

5.2. Step 2 – Specifying data sources

First all potential data sources (e.g. reports, sensors or surveillance cameras) are identified. Then the required information depths, input syntaxes, collection frequencies and transfer standards are defined. With respect to daily construction reports, this includes the design of the forms to be used for data collection.

5.3. *Step 3 – Generating and acquiring data*

Data are collected on a regular basis and made available to all authorized recipients. There may be a non-negligible time discrepancy between the collection and transfer of data. For example, daily construction reports are often not submitted to the client on a workday basis, but at the end of a working week.

5.4. *Step 4 – Converting data format*

In this step the preparation of the data for further processing is initialized. Depending on the data source a conversion is necessary (BITKOM, 2012). This means, that if data are available in a format unusable or less suitable for further processing, they must be converted into a format that can be (better) processed. Additionally, scanned paper documents are upgraded to machine-searchable files using ocr (optical character recognition).

5.5. *Step 5 – Transforming data*

The data are put into a structure required for analysis. In particular, the unstructured data are converted into structured data. It should be noted that unstructured data are subject to either no structure or an unknown structure (Taleb *et al.*, 2018). A clear structure is the prerequisite for being able to interpret data (BITKOM, 2012). However, the individual structural elements can still contain unstructured content (e.g. free text) after the transformation (see Figure 3). This is not a problem and is considered in process step 8. Furthermore, it is important to note that information is lost as a result of this conversion, since the result is merely a summary of the original data (Chen *et al.*, 2013). Consequently, the amount of output data is less than or equal to the input amount (Taleb *et al.*, 2018).

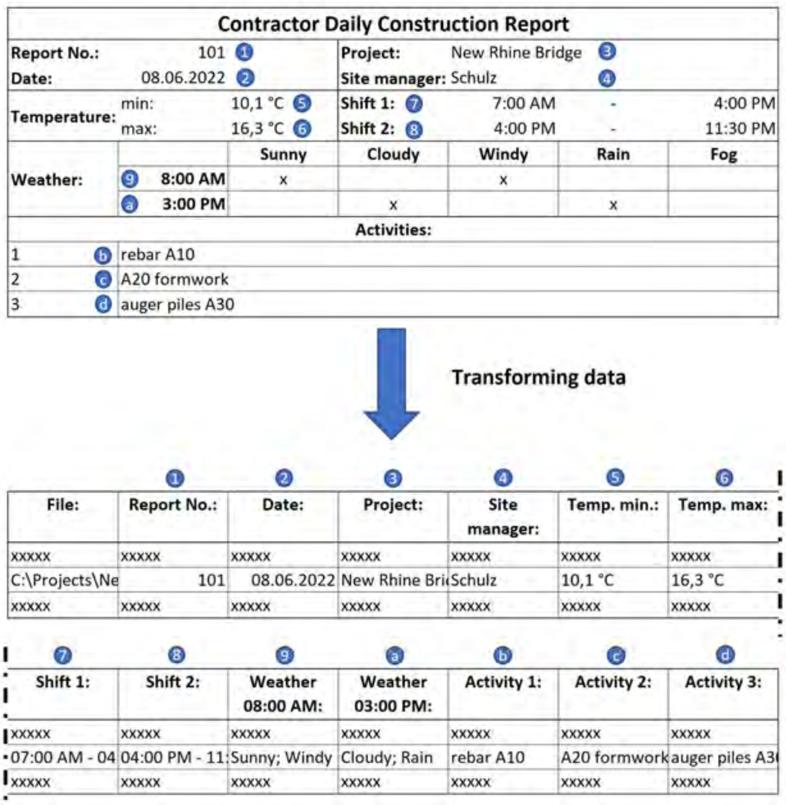

Figure 3. Transforming daily construction reports into structured data

5.6. *Step 6 – Superficially evaluating data*

It is necessary to evaluate data in advance before they are analyzed using time and monetary resources (Taleb *et al.*, 2018). Data are only useful, if they can be evaluated and used further (Goger *et al.*, 2018). For this reason, a superficial evaluation of the data is performed.

It is checked to what extent the data contain gaps that cannot be closed in process step 7. Furthermore, the result of the conversion of the unstructured into structured data is evaluated. The quality of the unstructured data depends on the structure into which it was incorporated (Taleb *et al.*, 2018). If no adequate structure could be defined, process step 5 may have to be repeated.

The evaluation results serve both as a filter for the less suitable data and for potential readjustment of the previous process steps.

5.7. *Step 7 – Cleaning data*

During data cleaning noise and contradictory data are removed (Han and Kamber, 2006). In this process step the contents are to be examined for unprocessable special characters that may have arisen in process steps 3-5 (e.g. "□" or "�" as a result of a failed conversion). In addition to noise, objectively incorrect content is searched for. For example, a date far before the project start may not be correct. These problematic contents have to be identified and corrected as far as possible. If the correction fails, the respective content must be removed from the data set or examined manually (depending on the size of the data set).

Furthermore, an attempt is made to fill in missing components of the data sets using the file-specific metadata as well as central registers. An example of a central register is a list of transferred plans. Plans are often stored in a project management system and provided with a manually or automatically created plan coding. Further information on these coded plans is entered in the list of transferred plans, e.g. sender or date of setting.

5.8. *Step 8 – Mining data*

In this step the cleaned data sets are subjected to an analysis. Methods are applied to detect patterns in the data sets and extract information (Han and Kamber, 2006; Chen and Zhang, 2014). This process step is particularly relevant regarding unstructured content within the structural elements. For example, existing free texts must be decoded and structured in terms of content (BITKOM, 2012). Free texts include the activity descriptions in daily construction reports.

For short or simpler texts, regular expressions can be used for analysis. Regular expressions are individual search patterns of varying complexity. For example, a search pattern "[a-zA-Z]{4}\s[0-9]{2}" is used to search for a word with at least four letters followed by a blank and a two-digit number. As the complexity of the regular expression increases the number of matches decreases and the probability of having identified the desired substring increases. Setting up such a search pattern requires that a certain structure can be expected within the string to be searched.

For more complex texts, e.g. NLP (natural language processing), a subfield of artificial intelligence, can be used. It is necessary to train the artificial intelligence, which requires a lot of time and a large amount of training data. This approach is less suitable for shorter texts.

5.9. Step 9 – Selecting data

Not all data provided by a data source need to be relevant to the analysis being performed. It is necessary to separate relevant from irrelevant data. For example, in a daily construction report only documented activities may be of interest, although other information is available, such as weather data. Unneeded information must be identified and filtered out automatically or semi-automatically (by manually defining the required information).

5.10. Step 10 – Verifying and integrating data

A large variety of data provides more information for problem solving as well as process optimization (Chen *et al.*, 2013). New insights are made possible by combining a wide variety of data formats (BITKOM, 2012). Therefore, it is important to combine the analysis results of the previously separately processed data sets in an "information integration step" (Doan *et al.*, 2009). This applies to both structured and unstructured data, because the greatest benefit is gained when analysis results of structured and unstructured data are combined (Weglarz, 2004). It is not reasonable to merge the data sets before the analysis in process step 8, due to partly completely different data structures, e.g. sensor data and daily construction reports. Separate processing promises higher efficiency and result quality.

In addition to merging, it is recommended to verify the generated data. For this purpose, an individual weighting factor should be defined for each data source. The weighting factor indicates how reliable the information from the data source is. To measure the reliability of a specific piece of information, the sum of all weighting factors of those data sources, which have provided the same information, must be determined. If the sum exceeds a defined threshold value, information is considered verified. In case of reliable data sources, the weighting factor may already exceed the threshold value. Verified information provides a more reliable basis for interpretation and decision making than unverified information. For this reason, the collected analysis results should be cross-checked against each other. In the last step information tuples are formed for subsequent schedule integration. Since tuples must be complete for schedule insertion, they are not formed at all, if individual components are missing.

5.11. Step 11 – Inserting into schedule

In the penultimate process step the information tuples (task, object and time vector) are solely incorporated into the schedule. No further data analysis is needed. This step would not be possible without the data being acquired, processed and upgraded to tuples in the preceding steps 1-10.

5.12. Step 12 – Discovering knowledge

In the last step knowledge about the construction progress is gained. Based on the generated target/actual schedule comparison deviations from the target state can be identified. This applies to both positive and negative deviations. If a schedule is created during construction, areas can be identified, where action is required in order to meet deadline targets. Whereas the comparison can be used as the basis for a construction claim when generated after construction is complete. The information tuples may also be used to make statements about actual production rates.

6. Challenges regarding data management

A qualitatively adequate data management for the semi-automated generation of target/actual schedule comparisons can only be realized, if potential sources of error are known and eliminated at an early stage. For this reason, 16 key challenges related to the four phases and 12 steps of data management (see Figure 2) are explained below. Additionally, potential coping measures are provided.

6.1. General challenges

- **Insufficient resources**

Typically, companies have too much data and too few resources to process them (Economist, 2011). Resources must be used for collecting, storing and utilizing data. The amount of resources used increases depending on the amount of data processed (Almeida and Calistru, 2013). Companies usually invest few to no resources in the conceptual design of a data management because the added value of proper data management is not recognized. If data management is to be designed and implemented, this usually has to be executed within a very short time. The result is a poorly developed and flawed concept. Time to carefully examine the design is usually not available.

Sufficient resources (especially time) should be allocated for the conceptual design, testing and implementation of data management.

- **Continuity**

A data management is normally designed as a one of a kind for a specific use case, i.e. it is tailored precisely to the expected data. Subsequently added data (sources) can only be made usable by modifying individual components of the data management. Either the way in which the data are processed or the analysis method used must be exchanged (Kaisler *et al.*, 2013). However, this subsequent adaptation can lead to the same data suddenly being interpreted differently. As a result, the previously analyzed data become unusable and require reanalysis. Furthermore, the unique nature requires a complete redesign for each new project, hereby wasting a lot of resources.

Data management should be designed in such a way that constant reconceptualization across projects is not necessary. A modular data management concept is conceivable, which can be used for a large number of projects. However, this requires that the individual components have to be designed as flexible as possible in order to be able to react to changing circumstances without modifications. Transfer standards must be defined for each module with regard to input and output data. Individual modules can be exchanged or modified depending on the specific project requirements as long as they comply with the transfer standards.

- **Velocity**

For schedule control and preparing forecasts it is important to be able to make a statement about construction progress as early as possible, as the scope for countermeasures decreases over time. A corresponding process, from data collection to schedule preparation, should therefore be completed within the shortest possible time. However, reading and interpreting data takes time. The more data are processed, the longer it will take (Almeida and Calistru, 2013). The complexity as well as the heterogeneity of the data also influence the velocity. Consequently, there is a need to deal with the speed at which existing data are updated or new data are generated (Chen *et al.*, 2013).

The programming of each component of data management should be optimized in terms of resource utilization. This includes keeping time-consuming file-level input/output operations to a minimum. Data should be loaded into the computer's memory for further processing. Likewise, efficient data structures should be used for intermediate data management. The use of parallel instead of serial computing can also have a positive influence on the speed of the analysis.

- **Errors in implementation**

During the implementation of a data management described in chapter 5, there will most likely be errors in the programming. If these errors remain undetected, they could lead to incorrect results when reading, converting and/or analyzing data.

It is recommended to plan sufficient time resources to be able to test the individual components and functions extensively. Especially in case of more complex computational operations, the input and output data of all intermediate steps should be examined. The actual output data should be compared with the expected. A sufficient check of the results enables the identification of potential malfunctions.

6.2. Phase 1 – Preparation and data acquisition

- **Missing or incomplete data**

The data needed to make certain statements may not be collected or may only be provided sporadically, resulting in information gaps, e.g. certain unrecorded construction trades. This is also due to data sources that fail irrevocably during construction and cannot be replaced one-to-one, e.g. sensors that are no longer available and can only be replaced by other models (from other manufacturers). As a result, the same information may no longer be collected.

An early demand analysis should be conducted regarding the required information. Additionally, data sources should be regularly checked and maintained during construction to proactively counteract failures. Faulty data sources must be restored to regular operation as quickly as possible. Especially for critical data sources, the installation of redundant systems should be considered. It should be checked whether the metadata of the data received are consistent in order to filter out inappropriate and manipulated data. Metadata are the information that describe a file in more detail, i.e. who created which file and when (Kaisler *et al.*, 2013).

- **Lack of data access**

Data collected at construction sites typically exist in fragmented (Harkonen *et al.*, 2019) form. This means that data are scattered across a variety of data sources, locations and stakeholders (Goger *et al.*, 2018). To make matters worse, data may not be exportable from embedded systems, such as data from computers integrated into construction equipment. As a result, stakeholders do not have access to all data, but usually only to their own. Data accessibility poses a significant challenge for the stakeholders (Goger *et al.*, 2018). Data must be accessible to the party that wants to further process it, e.g. to generate a target/actual schedule comparison. However, this can prove to be difficult, if the contractor collects the data and the client wants to process them. For this reason, data exchange between stakeholders is becoming increasingly important for successful project execution (Goger *et al.*, 2018). Nevertheless, companies want to maintain their competitiveness (Almeida and Calistru, 2013), which is why they are afraid of disclosing trade secrets through data and are therefore unwilling to hand over data (Raptis *et al.*, 2019). Additionally, they do not want to possibly disclose poor performance (e.g. worked too slowly) or misstatements made (e.g. on capacity usage).

Construction contracts should be adapted to advancing digitalization (Goger *et al.*, 2018). The obligation to submit data of a defined quality and quantity at specific times should be included in the construction contract. The originator of the data is responsible for the accuracy of the data to a certain extent (Kaisler *et al.,* 2013).

- **Structural difficulties**

Different data formats and mismatching structures are major challenges in data analysis (Kaisler *et al.*, 2013). Varying structures within the data of a data source mean that an analysis routine may have to be adapted several times or extensive reworking of the data may be necessary in subsequent process steps. This is the case, for example, with excel-based daily construction reports, in which the same information is entered in different places within a form across documents.

An existing basic structure of the data should be used, even if this slows down the analysis. For example, in a daily construction report the activities performed could be listed below a heading “Activities”. The challenge is to identify these headings or keywords and determine their position within the respective file. Using a relative reference (e.g. one line below), the information sought can be located. With this approach, individual case related modifications of an analysis routine are not required, since it is possible to react dynamically to varying structures.

- **Inadequate schedule**

It is possible that the schedule is structurally unsuitable for incorporating the construction activities documented by means of data. Two constellations are conceivable:

1) The schedule is too rough. This is the case if only a rough project-oriented schedule with main activities is available, but the construction activities are documented in a fine-grained manner at the level of a production-oriented schedule.

A post-detailing of the schedule should be made. This can be done in the form of a translation table, which is used to map the detailed information extracted from data to the rough schedule entries. For example, an activity “Installing rebar wall 1.01” extracted from a daily construction report would be assigned to a task “Building all walls on first floor”.

2) The schedule is post-detailed by the contractor during construction. This is the case when the schedule does not have the depth of content needed for effective control of the construction site. For example, instead of a single activity “Building all walls on first floor”, a subdivision into the individual walls as well as the individual steps of the production “formwork”, “rebar” and “concreting” is required. On the other hand, the construction work is only roughly documented.

Since accuracy cannot be achieved due to the rough recording of the construction work, the information could be linked to a summary task within the schedule instead of a (post-detailed) task. Alternatively, it could be checked which tasks from the post-detailing could potentially be considered as a reference task. Subsequently, the number of potential reference tasks should be reduced based on exclusion criteria, such as task already completed or prerequisites not yet met. The information is incorporated equally in all remaining schedule entries.

In both constellations, information obtained from data cannot be easily assigned to the tasks within the schedule. This inevitably leads to a lack of clarity in the information as a result of assignment problems.

6.3. Phase 2 – Preprocessing

- **Analog data**

In some cases, data are not transferred digitally, but only in analog form. These data have to be digitized subsequently, e.g. by scanning. Digitizing documents leads to unstructured image files. Even if the paper document is subject to a clear structure, the digital counterpart cannot be easily interpreted. To make matters worse, scanned documents are often skewed, covered with dust and scratches, have information overlaid by handwritten comments and signatures and have low image contrast due to poor scan quality. Some of these data are not (immediately) analyzable.

The digitized documents could be made analyzable by means of optical character recognition. The probability and quality of the analysis depend on the ocr software used and the state of the image file. It is recommended to optimize the image files before performing ocr in order to reduce noise. The contrast should also be increased so that the existing characters can be clearly distinguished from the background, e.g. in the case of white text on a gray background.

- **Loss of information due to interfaces**

There is an interface problem between common software solutions (Goger *et al.*, 2018). Data exported from one program cannot necessarily be used in another. Converting data into a usable data format can remedy the situation. However, information may be lost during the conversion because not all data may be transferred to the new data format. If this lost information is needed for further analysis, this poses a significant problem.

Conversion of data should be avoided as much as possible. Instead, an attempt should be made to revert to the source file, even though this potentially requires more effort in the design and implementation of data management.

- **Structuring unstructured data**

Unstructured data must be translated into sufficiently structured data (BITKOM, 2012). However, it can be difficult to find a structure into which unstructured data can be transferred. The quality of unstructured data is only as good as the structure which it can be fit into (Taleb *et al.*, 2018). Trying to extract a hidden (Doan *et al.*, 2009) structure from unstructured data can be difficult.

A basic structure within construction site data should usually be present. Data are predominantly produced for the purpose of documentation and must follow a certain basic logic in terms of content in order to be comprehended by third parties. Instead of trying to squeeze unstructured data into fixed, predefined structures, target structures can be designed dynamically. A key-value pair, consisting of a key or classification and information, could be extracted from data. This pair can be attached to an extensible data structure, such as an array or dictionary. Since the information is classified based on the associated key, a variance in the key leads to a different classification, which may cause the information to be interpreted differently or not at all.

- **Set rules for cleaning**

It may happen that rules for cleaning are defined that result in not only noise being removed. This includes unexpected outliers in the data, e.g. work was carried out on a component that should not have been started for several weeks.

In order to avoid unintentionally sorting out useful information (Almeida and Calistru, 2013) or to reduce this misbehavior to a minimum, sufficient resources should be invested in the development of the appropriate rules. For the development of rules, an extensive and heterogeneous data set should be used for testing purposes, so that the correct functioning of the rules can be thoroughly checked.

6.4. Phase 3 – Mining and verifying

- **Unnoticed misinterpretation of the information**

It may happen that data are interpreted differently than intended. Particularly in the case of large volumes of data, information analyzed by machine can only be checked sporadically by hand. A manual check of all information is too time-consuming and does not lead to the desired result, since the analysis could otherwise also be carried out completely manually. Furthermore, it is questionable whether all errors would actually be identified.

The input data and the analysis results of a sufficiently extensive and as heterogeneous as possible data set should be randomly checked for possible misinterpretations.

- **Content quality**

The information contained in the data is potentially too imprecise for further analysis because it is not clear when and where which tasks were performed. The use of such low-quality data is dangerous because it can lead to wrong decisions (Kiefer, 2016). Free texts in particular pose a major challenge. Among other things, spelling mistakes and abbreviations (Kiefer, 2016), irony (Möhring *et al.*, 2015) as well as ambiguity and idioms (Raptis *et al.*, 2019) make a machine evaluation difficult. If free text entries are permitted in daily construction reports, it is sometimes difficult for a third party to comprehend which specific activities were performed at which point. The written word does not necessarily express what was meant (Weglarz, 2004).

With regard to potential spelling errors, a certain error tolerance should be established via a measurable threshold value so that misspelled words can nevertheless be (correctly) analyzed. Compliance with this threshold (e.g. 20%) can be checked using a quotient. This quotient is composed, for example, of the Levenshtein distance between the misspelled word and predefined words from a dictionary (e.g. designations of buildings or components) in relation to the length of the misspelled word: (lev(word$_{misspelled}$, word$_n$ from dictionary) / length(word$_{misspelled}$)) < 0.2. An example for the misspelled word "cincrete" is provided in Table 1.

Table 1. Levenshtein example

Word$_n$ from Dictionary	Lev(word$_{misspelled}$, word$_n$ from dictionary)	Lev / Length	Match (< 0.2)
Ceiling	7	0.875	no
Circuit	4	0.5	no
Concrete	1	0.125	yes
Drywall	8	1.0	no

- **Selection of relevant content**

With advancing digitization more and more data are being collected from different data sources. However, not all data are needed for a specific use case. Much of the data are irrelevant and can be filtered out, but it is important to collect the relevant data (Almeida and Calistru, 2013). In order to distinguish relevant data from less relevant data, the relevance of data must be determined (Kiefer, 2016). It is not necessarily obvious which content is relevant and which is not. Differentiation may be difficult.

Data should be divided into three categories: relevant, suitable for reconciliation and irrelevant. Data that can be used to generate information tuples should be placed in the first category. Checking rules should be established to determine whether the remaining data can be located in the second category. For example, the concreting of a component requires a minimum temperature. If the considered data supply a component of the checking rule (e.g. outdoor temperature) these are to be assigned to the second category. The remaining data belong to the third category.

- **Lack of possibility for verification**

The use of unconfirmed information compromises the reliability of the data set (Kaisler *et al.*, 2013). Therefore, it must be checked whether the data reflect reality (Kiefer, 2016). Otherwise manipulated data could be included and distort the overall picture. For example, a site manager could add information to a daily construction report that does not reflect the actual activities performed. There is a need to find a way to collect different types of data to match their meanings (Chen *et al.*, 2013).

Deliberate vagueness in individual statements or within the schedule could be accepted. When generating schedules during construction, decisions should be made more cautiously. Where possible, construction progress in critical areas should be recorded and/or verified by manual visual inspection.

6.5. Phase 4 – Knowledge discovery

Phase 4 of data management takes on a special role. In this phase the analysis results of the previous steps and phases are processed graphically for the purpose of knowledge extraction. The main challenges associated with this phase are due to manual misinterpretation of the results. This, however, will not be discussed in further detail.

7. Conclusion

A twelve-stage concept for data management was developed, with which schedules can be generated semi-automatically from construction site data. With the implementation of this concept a fast and cost-effective preparation of target/actual schedule comparisons is possible.

Additionally, 16 key challenges related to the developed data management concept were discussed. Potential overcoming measures were suggested for these challenges. In practice, the challenges *lack of data access* and *content quality* usually prove to be the two most relevant. The partly deficient *content quality* can be traced back to three main aspects. Firstly, site managers attach little importance to the creation of documentation or data, as they focus on the progress and success of construction. Secondly, too little time is spent on documentation. Thirdly, *content quality* is influenced by the limited skills of the documentation creator in terms of the language to be used and the preparation of accurate records.

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Comparative Analysis of Linear Regression and Soft Computing Methods for Estimating Highways Construction Time and Cost in the Republic of Croatia

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Abstract:

Construction of road structures, including highways, on the Republic of Croatia territory often suffers from the planned time and cost deviations, whereby overruns are particularly unacceptable. In terms of costs, overestimated costs can also cause problems because it is more demanding to ensure more investment money. Therefore, the main research goal is to investigate relations between realized and contracted time, also realized and contracted costs of highway construction by applying predictive modelling – linear regression and some soft computing methods. In addition, the goal is to investigate the possibility of establishing the appropriate model for estimating the duration and cost of similar projects by using simple linear regression analysis, neural networks (NNs) and support vector machine (SVM), using the software DTREG. By comparing the accuracy of the obtained models using mean absolute percentage error (MAPE) and the coefficient of determination (R^2) as standard estimators of the model accuracy, the optimal models have been selected, and the possibility and conditions of their application in practice have been analyzed. Furthermore, the differences, advantages, and disadvantages in applying linear regression and soft computing methods in solving this and similar engineering problems were explored, primarily in time and cost planning.

Keywords: *roads; highways; time; cost; linear regression; neural networks; support vector machine*

1. Introduction

In the construction practice of roads, the contracted construction time and cost deviation from the planned values are common occurrences. Thus, the road projects' realization goal is to assess these values as accurately as possible and avoid or minimize time and cost overruns. In terms of costs, overestimated costs can also cause problems because it is more demanding to ensure more investment money in the preparation project phase. This can be achieved by accurately estimating of road construction duration and cost before signing a construction contract during project preparation. Therefore, developing and using scientifically based models obtained by applying adequate mathematical methods is critical to achieving these goals. In addition, browsing the finished roads' projects database presents the source of essential data and experience to consider the circumstances of new project realization in a more realistic way. Unfortunately, experience shows that time and cost, although the critical contract elements are often assessed empirically, without adequate scientifically or experientially based methods. This usually happens under deadline pressure as the time and cost information must be provided to enable further project activities. Thus, inherent uncertainties and risks, which are intrinsic to all roads projects, are neglected, resulting in the possible generation of time and cost deviations compared to those estimated in the project (Rwakarehe and Mfinanga, 2014; Al-Hazim and Salem, 2015; Tadewos and Patel, 2018; Narayanan et al., 2019; Kassa, 2020, Alshihri et al., 2022).

The focus of this paper is the issue of time and cost estimating in highway construction projects.

The paper begins with an Introduction, after which the State of the art provides an overview of current knowledge on the observed issues and an overview of prominent researchers. Chapter 3 provides a detailed definition of the paper's goal, while Chapter 4 defines research hypotheses. Chapter 5 describes how the research was conducted, the methods used, and the obtained results. Within Chapter 6, a discussion of the results was conducted, while the last chapter (Chapter 7) provides valuable conclusions.

2. State of the art

The problem of overruns on the contracted deadline and budget in construction projects is a global phenomenon (Petruseva et al., 2016; Gituro and Mwawasi, 2017; Bentil et al., 2017; Zaki et al., 2018; Tijanić and Car-Pušić, 2019; Simushi and Wium, 2020; Idrees and Shafiq, 2021) therefore, it is often at the center of research interest from various aspects of observation (Bromilow, 1969; Car-Pušić, 2004; Le-Hoai and Lee, 2009; Žujo et al., 2010; Petruseva et al., 2013; Petruseva et al., 2017; Tijanić et al., 2019; Car-Pušić et al., 2020b; Car-Pušić and Mlađen, 2020; Dahlin and Pesämaa, 2021; Alshihri et al., 2022; Oluwajana et al., 2022). Numerous researchers have focused on the issue of predicting the time and/or cost of road projects (Attal, 2010; Wang et al., 2010; Peško et al., 2013; Choi et al., 2014; Ćirilović, 2014; Elbeltagi et al., 2014; Hunter, 2014, Naik and Radhika, 2015; Adel et al., 2016; Barros et al., 2018; Tijanić et al., 2019; Dunović et al., 2021; Moghayedi and Windapo, 2022).

According to Car-Pušić and Mlađen (2020), it is necessary to monitor and register data on constructed structures to more accurately estimate the time-cost aspects of projects, to have sufficient information about the new projects, apply multiple assessment methods/models, and select the most accurate one.

In previous research, various mathematical methods and tools have been used to solve predicting construction time and cost problems, such as simple and multiple linear regression, “soft computing” methods (neural networks, machine learning, fuzzy logic), etc. (Plebankiewicz, 2018; Dunović et al., 2021). Regression analysis and neural networks make it possible to find patterns, links, and analytical and mathematical links between construction time/costs and independent variables and can provide a reliable answer to complex problems such as the more accurate the time/cost estimate.

Simple linear regression models in which the construction time is estimated based on one variable - construction cost (″T-C″ model), have proven to be sufficiently accurate (Bromilow, 1969; Car-Pušić, 2004; Le-Hoai and Lee, 2009; Joshi et al., 2021; Pokhrel et al., 2021). In addition, research has shown that inversion is also valid, and that construction cost can be estimated very accurately using the variable - construction time (″C-T″ model) (Skitmore and Ng, 2003; Žujo et al., 2010; Hwang, 2011; Kim et al., 2020), so collecting extensive databases with many variables is not necessary, just two variables are sufficient (construction time/cost). Furthermore, researchers have developed similar models in which the cost aspects of a construction project are estimated, such as ″ΔC-ΔT″ model (target: the contracted price overrun; predictor: the contracted time overrun) (Žujo et al., 2010) and ″C_R-C_C″ model (target: real construction cost; predictor: contracted construction cost) (Car-Pušić et al., 2020b, Car-Pušić and Mlađen, 2020).

The application of artificial neural networks for time or cost estimation with one independent variable (construction time/cost) has been researched by some authors (Car-Pušić et al., 2020b; Car-Pušić and Mlađen, 2020). In recent studies, a step forward has been made by developing hybrid models for estimating construction time and costs that combine process-based and data-driven models (Petruseva et al., 2017; Žujo et al., 2017; Car-Pušić et al., 2020a), where very high estimation accuracy models were obtained.

As a result of all this research, it can be concluded that the use of regression analysis and artificial neural networks is a promising approach for use in the initial phase of highway projects when usually only a limited or incomplete set of data are ready for time/cost analysis.

Following the example of previous research, within this paper, models for predicting construction time and cost have been developed, based on a database of road projects, with one predictive variable.

3. Research goal

The main research goal is to investigate relations between realized and contracted time, realized and contracted costs of highway construction by applying predictive modelling – linear regression (LR) and soft computing methods (neural networks (NNs) and support vector machine (SVM)). In addition, the goal is to compare those models and to identify the models that provide the most accurate time and cost estimates and provide guidelines for implementation.

The conditions of application for the most accurate time and cost estimation model will be analyzed, too.

Digital transformation in the management of highway construction projects will be encouraged through modelling. Through the application of technology and innovative processes, greater efficiency of such construction projects could be achieved, primarily in terms of greater accuracy when planning construction time and costs.

4. Research hypothesis

In the Republic of Croatia, the duration and cost of construction work in highway new construction are not contracted in real terms but with deviations. The contracted values are often estimated empirically based on experience or without any scientific-based methods. This research aims to prove the following hypothesis for the highways' construction:

1. There is a relation between real and contracted construction duration that can be mathematically modelled.
2. There is a relation between real and contracted construction costs that can be mathematically modelled.
3. Standard BTC (Bromilow T-C) model can be used to predict construction time by using construction cost.

The research hypotheses will be tested by applying LR, NNs and SVM to data on newly constructed highways and comparing the model accuracy. In addition, the application conditions for the most accurate time and cost estimation model will be analyzed.

5. Research methods, data base and data processing

The database was set up by using the documentation review and analysis. Data on contracted and realized highway construction durations and costs of 25 in total, built on the territory of the Republic of Croatia from 1995 on, were used. Prices in the database are expressed in Croatian kuna (HRK), and for the purposes of this paper are converted into Euros (€), according to the exchange rate on June 15, 2022. Descriptive sample statistics are shown in Table 1.

Table 1. Descriptive statistics of the highway database

Statistical indicator	T_C	T_R	$\lvert T_{DIFF} \rvert$	C_C	C_R	$\lvert C_{DIFF} \rvert$
Mean	466.80	432.72	117.12	3,829,651.49	5,288,861.51	1,459,949.85
Standard Error	46.68	61.35	38.62	587,697.77	876,607.45	347,844.52
Median	480.00	360.00	60.00	3,282,854.50	4,330,896.64	802,101.75
Mode	240.00	630.00	0.00	#N/A	#N/A	#N/A
Standard Deviation	233.38	306.77	193.10	2,938,488.87	4,383,037.27	1,739,222.59
Sample Variance	54,464.33	94,108.29	37,285.69	64,884,733,299,194.90	144,359,295,146,414.00	22,730,278,756,757.60
Kurtosis	-1.38	3.56	16.10	-0.11	0.05	0.39
Skewness	-0.07	1.55	3.72	0.08	0.14	0.26
Range	760.00	1,380.00	960.00	9,200,462.53	15,558,983.39	6,340,024.95
Minimum	80.00	60.00	0.00	272,209.40	262,961.44	9,247.95
Maximum	840,00	1,440.00	960.00	9,472,671.93	15,821,944.83	6,349,272.90
Sum	11,670.00	10,818.00	2,928.00	95,741,287.27	132,221,537.70	36,498,746.34
Count	25	25	25	25	25	25

T_C – Time Contracted (days)
T_R – Time Realized (days)
T_{DIFF} -Difference between realized and contracted time (days)
C_C – Cost Contracted (€)
C_R – Cost Realized (€)
C_{DIFF} - Difference between realized and contracted cost (€)

The average value of the time deviation of highway projects is 117.12 days with a standard deviation of 193.10 days. The minimum time deviation is 0, and the maximum is 960 days. Regarding the cost component of projects, the average cost difference is € 1,459,949.85 with a standard deviation of € 1,739,222.59. The minimum cost deviation is € 9,247.95, and the maximum is € 6,349,272.90.

Predictive Modelling Software DTREG is used for data processing and modelling, supporting a wide range of models (regression models, decision trees for regression, neural networks, support vector machine, etc.). The database must be an ASCII file in Comma Separated Value (CSV) format with values for one case per row and one column for each variable. One of the variables is the target variable, while one or more other variables are predictors. DTREG analyzes the data and generates a model that gives the best estimate of the target variable based on the available predictor values. The software allows selecting the model parameters from the multiple options offered.

In an attempt to obtain a more accurate time and cost estimation model, in addition to LR, some soft computing models have been used: General Regression Neural Network (GRNN), Radial Basis Function (RBF), and Support Vector Machine (SVM). These models were selected because they are suitable for continuous variables and for smaller databases. The Multilayer Perceptron (MLP) network has proven to be inappropriate due to too little data and was therefore excluded from further consideration. For all models, the expected optimal initial parameters provided by the software were used.

Several different estimation models have been developed in which the target and predictor variables were as follows:

- target: Time Realized (T_R), predictor: Time Contracted (T_C),
- target: Cost Realized (C_R), predictor: Cost Contracted (C_C),
- target: Time Realized (T_R), predictor: Cost Realized (C_R).

The error of the models was measured using the mean absolute percentage error (MAPE) and the coefficient of determination. The MAPE is a measure of prediction accuracy, and it is defined by formula (1):

$$MAPE = (1/N)\Sigma((realized\ values\text{-}contracted\ values)/realized\ values)[\%] \quad (1)$$

The coefficient of determination indicates how well data points match the approximation function which is obtained from the model – it is a measure of the general match of the model (Car-Pušić et al., 2020b).

For GRNN, the Gaussian kernel function was applied for the model with the target T_R and predictor C_R, σ values were calculated for each predictor variable (min σ = 0.0001 and max σ was 5, with 30 search steps). For the model with the target T_R and predictor T_C min sigma was also 0.0001 and max σ was 10, with 30 search steps, but the kernel function was the reciprocal function; and for the model with the target C_R and predictor C_C the minimal and maximal values for sigma were 0.0001 and 5 respectively, with 50 searching steps and the kernel function was also the reciprocal function. For all three models with the GRNN the Leave One Out (LOO) method was used for validation during the optimization process. Each training model was built with all training rows except one and then, the error was evaluated for the excluded row. This was repeated for all rows, and the error was averaged (Sherrod, 2014).

The initially defined type of SVM model Epsilon-SVR model was used for all three models using SVM. Another possible option offered by the DTREG software is the V-SVR model. The differences that may arise are small and the other model has not been applied. Radial Basis Function (RBF) has been implemented as the kernel function for the model with target T_R and predictor T_C. For the model with target T_R and predictor C_R and for the model with target C_R and predictor C_C the kernel function was chosen to be the reciprocal function, offered by DTREG as second option for the kernel. In the most of the cases RBF kernel produces the best results, but depending on the structure of the data, the reciprocal kernel can also produce good results, as in our models. Kernel function transforms the input data into an n-dimensional space where a hyperplane can be constructed and the optimal approximation linear function will be obtained in the new space (Sherrod, 2014; Petruseva et al., 2017).

Model validation for all 3 models is performed by Cross-validation method with 10 cross-validation folds.

The processing was performed with normalized values of variables to achieve greater model accuracy, which reached the stated goal. The obtained results discussed in the next chapter are presented in tables 2, 3, and 4.

Table 2. Results for linear regression, neural networks and SVM for time, T_{Rnorm}-T_{Cnorm}

Parameter	LR	GRNN	SVM	RBF
R^2	0.61	0.76	0.70	0.69
R	0.98	0.88	0.85	0.83
MAPE /%/	5.67	<u>3.65</u>	4.54	5.13

Table 3. Results for linear regression, neural networks and SVM for cost, C_{Rnorm}-C_{Cnorm}

Parameter	LR	GRNN	SVM	RBF
R^2	0.97	0.97	0.98	0.95
R	0.98	0.98	0.99	0.97
MAPE /%/	0.89	0.81	<u>0.65</u>	1.10

Table 4. Results for linear regression, neural networks and SVM for T_{Rnorm}-C_{Rnorm}

Parameter	LR	GRNN	SVM	RBF
R^2	0.40*	0.53	0.50	0.28*
R	0.64	0.74	0.72	0.55
MAPE /%/	7.93	<u>7.15</u>	7.25	8.61

6. Discussion of results

In the first performed processing with the original values, the GRNN gave the best result of 25.65% for MAPE, but with the low value of R^2, which is 46.21 in the case of T_R-T_C. In the case of C_R-C_C, MAPE is 16.07%, with R^2 of 95.68 and R of 97.84. In the case of T_R-C_R, MAPE is above 65% in all considered models, which is not an acceptable value.

In the second processing with the normalized values undertaken to improve the models' accuracy, significantly better results have been reached (Tables 2, 3, 4). The best result was obtained in the case of the C_{Rnorm}-C_{Cnorm} function where MAPE is 0.65 and R^2 is 0.98 for the SVM model. In the case of the T_{Rnorm}-C_{Rnorm}, unacceptable values of R^2 were obtained for LR, SVM, and RBF models.

In practice, one always wants to plan as accurately as possible, so any contribution to increasing accuracy is important. Developed models can be used for rapid and efficient analysis of the expected highway construction cost and time, and they can serve all project participants. Although the models were developed in the Croatian context, the approach used may be applied to developing similar models in other countries.

The development of such models fulfills the criteria of smart construction and digital transformation, where through the development of new, innovative processes and models, existing construction planning is improved, costs and time are rationalized, and the overall management of construction projects, in this case, highway construction projects, is improved. The development of the presented prediction models would not be possible without the application of new resources (technology and software) that exploit the power of data and solve complex problems in a very short time by finding links and connections between variables, generating very accurate output results. The implementation of predictive models will enable better project decision-making, efficiency, value for money, and sustainable project outcome, which has positive effects on the entire society, economy and environment.

7. Conclusions

The real time and costs of new highway constructions often deviate from the contracted values whereby overruns are particularly unacceptable. As for the costs themselves, in the case of their underestimation, there is a risk of successful completion of the project, but even their overestimation is not recommended, because in the project preparation phase it is more demanding to provide more investment money. The reason for overruns is in the empirical approach when estimating cost and time, although they are critical contract elements. Namely, they are often assessed empirically, without adequate scientifically or experimentally based methods. The aim of the research was to investigate several relations between real and contracted time and cost variables by using linear regression and soft computing-based methods and define the best models for time and cost estimation in the preparation project phase.

One of the investigated models is the relation between C_R and C_C that is the model that defines the functional dependence of the real price C_R and the planned price C_C, thus obtained corrected price should be taken as the contract price. This would reduce the risk of the contract price being inaccurate. The best results were obtained for the C_{Rnorm}-C_{Cnorm} relation.

Two other models are related to the estimation of construction time, one of them the relation between T_R and T_C, and the other the standard BTC model.

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Applicability of Blockchains in the Construction and Real Estate Industry

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Abstract:

Blockchain technology has been an intensively discussed and a controversial topic since the rise of the cryptocurrency Bitcoin in the last years. A common opinion in the scientific literature is that the great revolution is not the Bitcoin itself, but rather the blockchain on which the cryptocurrency is based. Originally the Bitcoin blockchain was solely developed to solve specific problems of digital money (e. g. the problem of double spending and removing a trusted third party). Nevertheless, many authors believe that blockchains will revolutionise a wide range of industries as e. g. the energy, financial, real estate and construction sector. The three main characteristics attributed to blockchains are *decentralisation*, *immutability* and *trust generation*, respectively making a trusted third party obsolete. Since the blockchain has become a success story together with the rise of the Bitcoin, people are trying to use it separately from the Bitcoin network and believe that this will lead to efficiency gains and time and cost reductions. Nevertheless, an actual use case on a larger scale has not been found so far in the last 13 years (the blockchain as part of the Bitcoin was introduced in 2009). The main reasons for the lack of real use cases are explored in this paper and it is shown that a meaningful implementation of blockchains in the real estate and construction industry is quite difficult or even impossible and probably also not desirable. This is demonstrated by explaining the so-called *"blockchain trilemma"*, the *"oracle problem"* and the game theoretically required *dependency between a blockchain and its corresponding native coin*.

Keywords: *blockchain; bitcoin; oracle problem; blockchain trilemma*

1. Introduction

The success of the Bitcoin network has led to increasingly frequent public discussions about cryptocurrencies and blockchains. The blockchain is promoted as a technology that – usually with some necessary "improvements" compared to the original Bitcoin blockchain – may be used for various industries to achieve efficiency increases as well as cost and time reductions. These assumed improvements result from a misunderstanding of the Bitcoin network and the capabilities of blockchains, as well as the desire to transfer the characteristics of the Bitcoin network to other use cases or at least to use the blockchain hype for marketing purposes. Nevertheless, even 13 years after Satoshi Nakamoto published the Bitcoin white paper in the year 2009, in which the blockchain was presented as an aspect of the Bitcoin network, alternative applications for the blockchain are still being sought in business and research.

In Germany for example, several university chairs (University of Osnabrück, University of Duisburg, Technical University of Dortmund, Technical University of Munich etc.) are working on the topic and in some cases special competence centres (Blockchain Center

Frankfurt School) have been created for this area of focus. In the private sector, consultancy on blockchains is offered by companies such as IBM, Deloitte, E&Y and JLL.

At the same time, governments in the European Union are working on a suitable regulation for Markets in Crypto Assets (MiCA) in an attempt to create a legal framework for digital assets. Earlier this year, there were even attempts to ban cryptocurrencies that use the energy-intensive proof-of-work (PoW) consensus mechanism, which were rejected for the time being (Merten, 2022).

A widespread view in the scientific literature is that Bitcoin would not offer any real added value, but that the hype around it and other cryptocurrencies distracts from the really significant aspects. The blockchain, as the underlying technology, would have a comparable status to the Transmission Control Protocol/ Internet Protocol (TCP/IP) (the basis of the internet) and could be much more than just the vehicle for cryptocurrencies (Jedelsky, 2019, p. 254; Mehrwald, 2022).

Supposedly, the blockchain would be a digital and tamper-proof database for any type of value, distributed across many individual computer systems around the world. Users would be able to transfer digital values and this transaction would be attached to the sequential database as a new block (IBM, 2022; Universität Duisburg Essen, 2022). In the real estate industry these values could be, for example, land registry rights or contract terms (smart contracts), circumventing intermediaries, such as real estate agents, and instead connecting buyers and sellers directly (Lipsky, 2019, p. 219). Due to the complete traceability of information on its sequential database, the blockchain would be especially well suited for mapping valuable physical assets (Jedelsky, 2019, p. 256). An example in the real estate industry are crowdfunding companies claiming that by using the blockchain ("tokenisation") they would enable investors to have genuine fractional real estate ownership (La Rubia, 2021).

Another opinion is that publicly visible and permissionless blockchains (e. g. Bitcoin) are useless due to the lack of data protection, but private blockchains operated by companies would solve this problem and offer added value. After all, the blockchain could just as well be managed by a central authority or a private company (Verheye, 2017, p. 465; IBM, 2022).

Despite this great interest in using the blockchain, to date the authors are not aware of any use cases that go beyond a pilot project and actually have economic success, bring efficiency gains or could not be managed just as well without the blockchain. In the following the main reasons for the missing applicability of blockchain in other application areas (than Bitcoin) and in particular in the construction and real estate industry are explored.

2. Research questions

For this purpose, basic functionalities of the Bitcoin network (as the only existing meaningful use case of a blockchain) are identified and the interconnections of the functionalities are analysed. The goal is to try to clarify misconceptions about the capabilities of blockchains.

The following (research) questions will be answered:

- What are the (distinctive) characteristics of the Bitcoin network and how are they achieved?
- What are the limitations of blockchains?

- What are the potential applications of blockchains in the construction and real estate industry?

The (research) questions will be mainly answered based on a literature review. In particular, the economic, technical and physical characteristics and principles of the Bitcoin network will be addressed in order to compare them with supposedly divergent applications of the blockchain.

3. Background on Bitcoin and blockchain

In the following chapters 3.1 to 3.3 the Bitcoin network is clarified in more detail. The main goal is to show, why the Bitcoin network was created and what purpose it serves. Furthermore, it is explained that a number of prerequisites are required to enable the characteristics of the Bitcoin network and that simply using a blockchain is not sufficient to achieve them. In addition, it is illustrated that the blockchain itself is only one component among many that make the Bitcoin network *censorship-resistant*, *secure*, *immutable* and *decentralised*.*Purpose of the Bitcoin network*

Bitcoin is electronic peer-to-peer cash. It solves the very specific problem of sending digital money without a trusted intermediary such as a bank or other payment service provider (e. g. PayPal). In the real-world money can be exchanged between individuals without having to trust the other party because the money is trusted, and the authenticity and existence of real money can be physically verified. In the increasingly digitised society payments are mainly made via the internet. This means that the transaction partners have to trust central third-party actors to verify the payments.

As Pritzker concisely summarises: “Money has changed from a physical thing you can carry, transfer, and verify yourself, to digital bits that have to be stored and verified by a third party that controls their transfer.“ (Pritzker, 2019, pp. 9–10).

Although the digitalisation of money leads to increased payment convenience, the power over payment flows is concentrated in the hands of the payment service providers and could be theoretically abused by authoritarian systems. As a result, e. g. opposition members could be prevented from buying goods and services or entire countries can be excluded from international payment procedures (e. g. Russia, Iran). To avoid this, Bitcoin offers a solution through the decentralisation of money. (Pritzker, 2019, pp. 9–10).

While it is technically and game-theoretically trivial to process digital payments in a centralised system, it becomes problematic when two distrustful or malicious parties want to exchange value without a trusted intermediary. In the following, this trust-creating third party is referred to as *a trusted third party* (TTP).

The exclusion of a TTP for payments between two peers is the essential purpose of the Bitcoin network (Nakamoto, 2008, p. 8) and is only made possible by a trade-off (see chapter 4.2). Consequently, the basic and most important premise for any possible use case of the blockchain must be the desire for *decentralisation and the exclusion of a TTP*.

3.2. Characteristics of the Bitcoin network

The Bitcoin network consists of so-called nodes (distributed computers that propose and verify transactions) and miners (service providers that write the transactions into the ledger and secure the network with their computing power). A key characteristic that enables the Bitcoin network not to require a TTP for digital transactions and at the same time makes it resistant to censorship even by state authorities is its decentralisation (see figure 1).

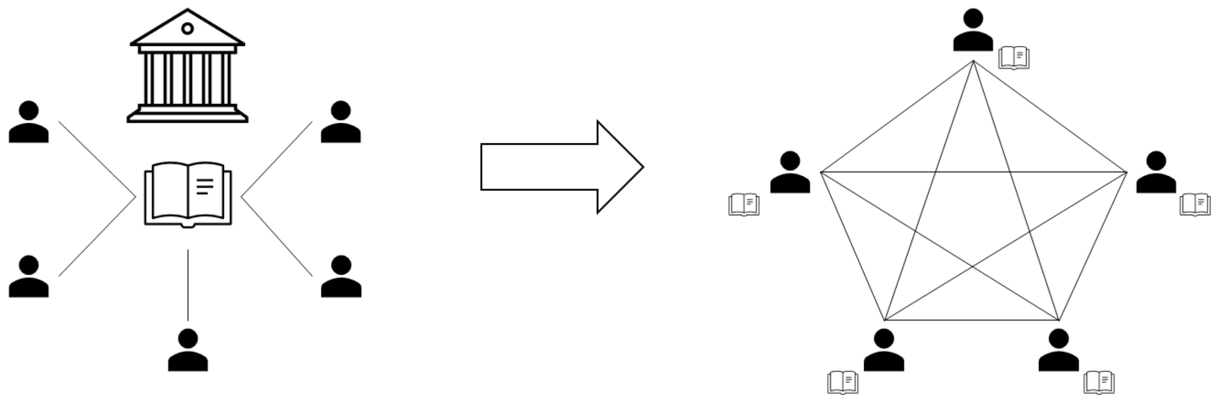

Figure 1: Decentralisation in the Bitcoin network (Pritzker, 2019, pp. 17 –18)

Decentralisation, in the context of the Bitcoin network, means on the one hand that the *transaction history* is distributed to each *network node* and thus there is no single point of failure in the network. The failure of a single node does not affect the functioning of the network. On the other hand, decentralisation means that consensus (what is the truth in the network) is distributed to the network nodes and there is *no central authority in the network* that controls the transaction history or the network itself (Jedelsky, 2019). A crucial characteristic of the Bitcoin network and also a unique selling proposition is that the person or group using the pseudonym Satoshi Nakamoto is not known and has disappeared since his last e-mail on 23rd April 2011. Consequently, there is no development team, no CEO and no marketing department and thus there is no one who could be threatened or pressured to shut down or change the network. In the network, which has functioned uninterruptedly and without error since its inception, all members (nodes) have equal rights.

This equality in the network implies, that access to reading and writing rights must be unrestricted. Each participant must have unrestricted and equal access to the entire transaction history in the network in order to be able to independently verify the validity of the ledger. One of the core principles of the Bitcoin community states: "Don’t trust, verify!". The necessary trust in a TTP is replaced by transparency and the resulting possibility of individual verifications. In order to maintain complete transparency towards non-members of the network, it should not be possible to exclude anyone from the network. This results in the requirement that the network must be permission-less and public.

As an example, the Bitcoin blockchain and its entire transaction history can be viewed by anyone via the ‘mempool.space’ website. It is possible to trace every single transaction back to the Genesis-block (the first block mined by Satoshi Nakamoto), including the associated sender and recipient address.

The final distinctive feature of the Bitcoin network is the *immutability* of the transaction history and the resulting irreversibility of transactions. It was Nakamoto's declared goal to enable irreversible payments in the digital space. To achieve this goal and also to solve the problem of double spending, he proposes in his Bitcoin white paper a distributed *peer-to-peer timestamp server* that creates a computational proof of the chronological order of transactions

(Nakamoto, 2008). This distributed peer-to-peer timestamp server based on computational proof is what is currently in many cases referred to as a blockchain.

3.3. Proof-of-work as prerequisite for a decentralised blockchain

As described in chapter 3.2 Nakamoto does not use the term blockchain in his white paper. However, the term describes the way the network operates well insofar as the transaction history of the Bitcoins is recorded in sequential data blocks, each with a limited capacity (approx. 2 MB). Every time two members of the network want to add a transaction to the blockchain, they announce it to all other participants in the network and write it into a new data block. On average, every 10 minutes, the so-called *proof-of-work* (PoW) process is completed and the data block with the transactions is attached to the chain (see figure 2).

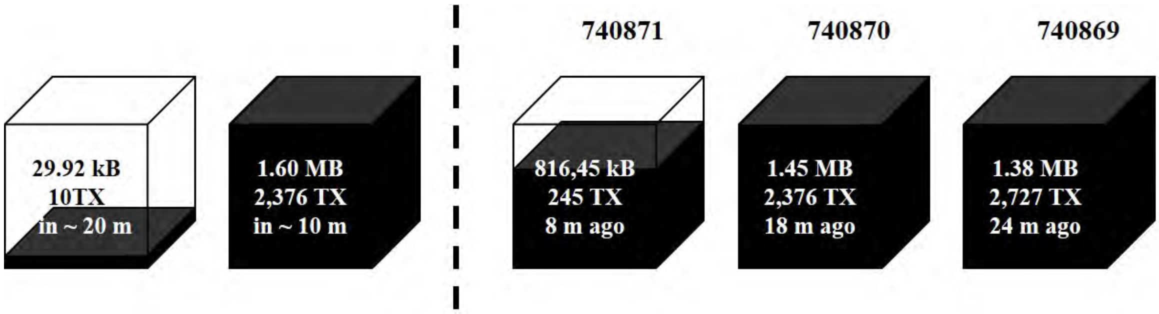

Figure 2: Schematic representation of the Bitcoin blockchain (source: mempool.space)

In figure 2 a schematic extract of the Bitcoin blockchain is shown. On the right side of the vertical line, the already confirmed blocks are shown with their respective position in the blockchain (number above the block). On the left side are the blocks whose confirmation is still pending. The blocks are populated with information about the block size, the number of transactions (TX) that have been validated by them and when they were or will approximately be validated. The process, by which in the Bitcoin network it is decided who gets to write a block of accumulated transactions to the ledger, is often described as a complicated arithmetic problem or cryptographic puzzle, but it is more accurate to think of it as a kind of lottery. In an open system with many participants, where no one should be made vulnerable, it makes sense to let probability decide who gets to write in the ledger. In this way, no one can be compromised by threats of violence or bribery. However, the following problems must be solved (Pritzker, 2019):

1. in order to avoid that a TTP has to issue the lottery tickets and thus obtains more power, all participants must have the possibility to create their own lottery tickets.
2. these tickets must not be free of costs, so that no participant is able to monopolise the lottery by generating a large number of tickets for free.
3. the other participants must be able to easily determine that the lottery has actually been won by a legitimate ticket.

The PoW is the solution to these problems proposed by Satoshi Nakamoto. In fact, however, it was developed as early as 1993. It involves a “random chance process that requires many computations to find a winning number. However, it only takes a single operation to verify the solution.” (Pritzker, 2019). Via physical laws, or more precisely via the first theorem of thermodynamics, it is ensured that participants can only take part in the lottery if they expend electrical energy and thus costs.

Furthermore, the PoW is an asymmetric process. Much more energy and higher costs are required for the miners to execute the PoW than for the other network members (nodes) to verify that it has been executed correctly and that the new block is therefore legitimate.

If a miner wins the lottery and is allowed to attach a block, he also gets the opportunity to write a *coinbase transaction* in the blockchain. With this transaction he receives a certain amount of bitcoin as a reward that are transferred to his address (Pritzker, 2019). The so-called *blockreward* (coinbase transaction) is the miner's reward for using electrical energy and makes mining potentially profitable. The competition for the block reward and thus for the attachment of a new block makes it possible to clear transactions without a TTP. (Ammous, 2016).

Due to the high costs (e. g. energy and hardware costs) of the PoW and the asymmetry in the evaluation of the output, fraudulent behaviour on the part of the miners becomes unprofitable. In order to receive the block reward, the miner must play by the rules of the network, because otherwise his block will be rejected by the network. (Ammous, 2016). Through the PoW a decentralised consensus without TTP is achieved.

In his white paper Nakamoto describes, how the PoW also leads to increasing security in the network. The blockchain is the concatenation of the consecutive PoW processes. Once the computing power for the PoW has been expended, the block cannot be changed without that power being expended again. Since following blocks are chained after it, the power to change the block would include the repetition of all subsequent blocks (Nakamoto, 2008).

This means that the security or immutability of a blockchain is based entirely on the computing power provided for the PoW and its verification. Or as Ammous writes: “Blockchain technology can best be understood as the conversion of electric power to verifiable undisputed records of ownership and transactions” (Ammous, 2016).

It is estimated that if an attacker had the energy of the entire Bitcoin network (annual energy consumption of a medium-sized country) and also the entire specialised Bitcoin hardware (Application Specific Integrated Circuits; ASICS) at their disposal - which is practically impossible - it would still take over 700 days to rewrite the entire history of the blockchain (Bitcoin network graphs, 2022).

4. Limitations of blockchains

Before examining some potential applications of blockchain outside digital currencies and specifically in the construction and real estate industries, first the limitations of the technology and interdependencies of various blockchain properties are discussed in the chapters 4.1 to 4.3. Three main aspects are explored: *native coin /currency*, the *blockchain trilemma* and the *oracle problem*.

4.1. Native coin / currency

From a technological point of view, in which the blockchain is to be used as a decentralised and unchangeable database to replace a conventional (centralised) database, the purpose of a required native currency (e. g. Bitcoin) linked to the blockchain is incomprehensible. However, this view results from a misunderstanding of the interdependency between the native currency and the network.

It was stated in chapter 3.1 that the blockchain was only designed to remove the need for a TTP. In the chapters 3.2 and 3.3 it was discussed that the exclusion of a TTP is made possible by creating a decentralised and transparent network and enabling decentralised consensus via the PoW. It was noted that the reward for the provided service by the miners is the issuance of the native currency (blockreward).

The currency and the network are thus two components of a *symbiotic system* of game-theoretic incentives. The currency provides the incentive for the miners to make the network more secure and practically immutable by converting energy into computing power. It follows that miners only have an incentive if the network's currency has credible monetary properties, or if a financial return can be achieved with it. From this dependency it can be concluded, as Ammous describes, that every blockchain competes for the use case of money (Ammous, 2019).

It is *essential* that the miners are paid in the native currency of the network, as there is an intrinsic interest in the functioning and longevity of the network. Moreover, if the miners were paid in any other currency, *decentralisation would be lost* because whoever pays the miners would have control over the operability of the network. A decentralised network based on PoW becomes more and more secure as the number of participants increases, while a centralised network becomes more and more insecure as the number of participants with writing rights increases, because each new participant represents a potential risk (Ammous, 2016).

A supposed solution to this dependency between network and coin is the use of so-called *private* or *enterprise blockchains*. These are blockchains with restricted access (in contrast to a public blockchain like the Bitcoin network). Access is granted by a central authority or a limited number of authorised members (Verheye, 2017).

Basically, the term "private blockchain" is a *contradictio in adiecto* (contradiction in apposition). As described in the previous chapters, the purpose of a blockchain is to establish trust and consensus in a decentralised system with unknown participants and to exclude a TTP. Accordingly, private blockchains make fundamentally little sense because a TTP is reintroduced (Gabison, 2017). Trust between the database participants is established through the identifiability of the participants and the possibility of holding them legally accountable (Ammous, 2016). A private blockchain may be distributed across multiple devices, but its security is still dependent on a central party granting access or paying those who provide the computing power to secure the network. One of the main advantages is lost and a centralised database could be used as well.

4.2. Blockchain trilemma

The characteristics of security and decentralisation of the Bitcoin blockchain through PoW were discussed in the previous chapters. However, these characteristics are in tension with the scalability of the technology, because the decentralised data storage and the resulting high latency times limit its throughput (BSI, 2019). This interaction is described by the so-called blockchain trilemma (see figure 3).

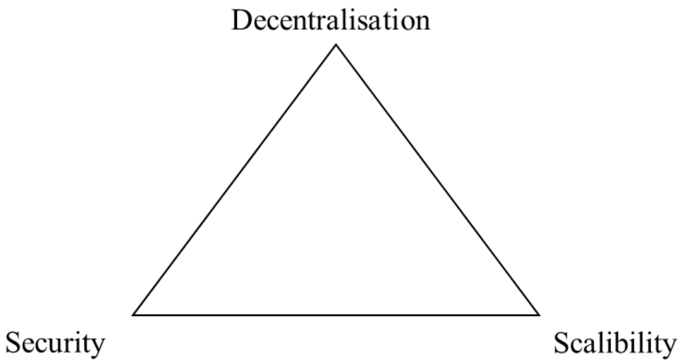

Figure 3: Blockchain trilemma

The blockchain trilemma means basically that a distributed database can only maximise two of the three characteristics of security, decentralisation and scalability. It is considered impossible that all three goals can be achieved at once. The Bitcoin network, for example, relies on decentralisation and security to be resistant to censorship and attempts of manipulation by state governments (bCyber GmbH, 2021).

An example of a limitation of scalability in favour of the decentralisation of the Bitcoin network is the block size limited to 2 MB as stated in chapter 3.3. On average, a block is currently 1.16 MB in size (cryptolist.de, 2022). The limitation of the block size is fundamental because every participant must be able to download and verify the entire blockchain transaction history on a commercially available hard drive. The entire Bitcoin blockchain currently requires about 400 GB (cryptolist.de, 2022) of storage space and can thus be verified by every participant at affordable hardware costs. If the block size would be increased, more transactions could be processed, but the blockchain's storage space requirements would increase significantly. Therefore, the hardware would only be available at high hardware cost and the blockchain would become more and more centralised because fewer participants could pay for the required storage space.

It is at least questionable whether there would be any meaningful files (e. g. plans, computer models) in the construction and real estate industry with a maximum size of 2 MB that could then be stored on a decentralised blockchain.

Around 250,000 transactions are processed worldwide on the Bitcoin network every day (cryptolist.de, 2022). This equates to less than 3 (2.89) transactions per second. If the decentralised storage requirement and the decentralised consensus mechanism (PoW) were removed from the network, a single commercially available laptop (14,000 transactions per second) configured accordingly could execute the daily number of transactions in under 20 seconds. For the annual global number of Bitcoin transactions this laptop would need a little more than 2 hours. The remaining problem is to trust the security measures and the owner operating this laptop (Ammous, 2019).

Therefore, it is incomprehensible, why some authors assume that the use of a truly decentralised blockchain could have an efficiency or cost advantage compared to centralised database solutions. The exclusion of a TTP in the Bitcoin network is only made possible and ensured by cost-intensive redundancies and PoW. A central database is, in any case, by far more efficient and less expensive.

4.3. Oracle problem

The oracle problem describes the system-immanent restriction of a blockchain (or a database in general) not being able to process information from outside of the network. At least not without depending on input from a so-called *oracle* (human, sensor etc.). Therefore, the integrity protection of a database does not include the *import of real-world data* provided by a TTP via an interface (BSI, 2019; Chainlink Foundation, 2020).

The oracle problem always exists when *real goods* are traded digitally, or contracts are linked to real-world conditions. An example of the oracle problem in the real estate industry is the trading of digital real estate tokens, where investors usually do not have the opportunity to examine the properties more closely. They have to trust that the company, from which they buy the real estate tokens, provides correct information about the asset and does not have fraudulent intentions. For example, they must rely on the following information:

1. the property exists in reality and is owned by the seller.
2. the property is as described and has no hidden deficiencies.
3. the shares of the respective rental income are paid out to the amount the investor is entitled to.
4. the share purchased is not subsequently diluted.

However, trust in the input of an oracle is not only required with a blockchain-based database, but also with a conventional (central) database. If the functionality of the blockchain can only be ensured through the input of an oracle, a TTP will be reintroduced. The essential characteristics of decentralisation and immutability are lost and the main goal of a blockchain is missed; instead, a central authority decides on essential inputs and their correctness.

The oracle problem also extends to the enforceability of ownership rights. In the Bitcoin network there is an absolute position of ownership over the native currency, which means that only the person who has the private key to a network address can initiate a transaction. There is no possibility for e. g. a bank, a hacker or a government institution to freeze or confiscate the coins without this key.

In contrast, property rights to real assets generally have to be enforced by an authority (the government or its institutions). For example, if a building is illegally occupied, a court order is first required, which is then enforced by law enforcement agencies. However, this also means that even if ownership rights to a property are stored immutably in a blockchain, they only remain valid as long as they are accepted by the government (TTP). If a government decided that owners should be expropriated, it would not care at all what is written in a blockchain.

This indicates that the only transaction where a TTP can actually be excluded is the transaction of the native coin itself and the record of its ownership. The blockchain is only as secure and reliable for other assets as the TTP that creates the link between the blockchain and the asset (Ammous, 2016). In these cases, efficiency and cost disadvantages from using a blockchain can be avoided by using e. g. a conventional central database.

5. Potential applications of blockchain in the construction and real estate industry

In general, start-ups and research projects related to blockchain technology can be assigned to three clusters consisting of digital payments, contracts and database/record management (Ammous, 2016). Consequently, in the construction and real estate industry, the blockchain use cases will particularly include the two clusters contracts and database/record management. In the following chapters 5.1 and 5.2 some important use cases are described and critically discussed.

5.1. Smart contracts

In the blockchain context, a *smart contract* is usually an executable programme whose code is sent to the blockchain in a transaction and executed by the network nodes as part of the validation process. The immutability of the blockchain is intended to prevent subsequent changes to the programme code and the automatically running validation process prevents the execution of the contract from being stopped. (BSI, 2019).

Basically, smart contracts are intended to *automate the execution of contractual terms*. Unfortunately, the application of smart contracts is limited to access only data that is stored within the own blockchain. However, many contracts should be able to react to real-world events that happen outside of the blockchain (Wüst and Gervais, 2017). An example are construction contracts where the construction work must be inspected by a site manager before the progress bill can be paid; an automatism of the process is not existing any more or is at least disturbed by a third party (oracle problem). Moreover, a smart contract does not work in the other direction either. If an advanced payment is made inside the blockchain, the smart contract cannot trigger a real-world event outside the blockchain without the use of an executing TTP (e. g. carrying out a delivery order of construction material to the site).

Another concern is the additional complexity of smart contracts and the associated vulnerability to failure. The basic idea that proponents of smart contracts promote is that "code is law". Transactions executed by smart contracts are supposed to be final due to the immutability and security of the blockchain. However, on top of the already complex legal layer of the contract, the software of the smart contract has to be programmed by a contract party or a third party and it is unclear who is liable in case of errors in the programmed code of the smart contract (unsolved liability issue). If there is an error in the code of the smart contract, there should be the possibility of reversing it. But this fundamentally contradicts the characteristics of a blockchain to be immutable and secure.

A popular example of this problem was a smart contract hack on the *Ethereum network*. The second largest blockchain in terms of market capitalisation is marketed as a smart contract platform. The first major implementation of a smart contract on the Ethereum network was the so-called Decentralised Autonomous Organization (DAO) in 2016. 150 million USD were invested in this smart contract when an attacker executed the program code in such a way that about a third of the assets was redirected to the personal account of the attacker (Ammous, 2019). Since the investors had agreed that their money would not be controlled by anything other than the programme code, there could be no question of theft. The attacker had executed this programme code as it had been accepted by the investors. As a reaction to this theft the developers of Ethereum created a new version in which this bug in the programme was eliminated. Finally, the attacker's funds were confiscated and paid out to the victims.

In summary all human management activities fundamentally contradict the goal of substituting a contract with program code. The principle of "code is law" is undermined by these activities, calling into question the very basis of smart contracts (Ammous, 2019; Wüst and Gervais, 2017).

5.2. Database management

A popular alleged use case for blockchain in the real estate and construction industry is its use as a database or in particular a land registry database (Kairos Future, 2017; Noll, 2019). In conjunction with a smart contract the land register inscriptions could be changed automatically when e. g. a mortgage has been paid off. However, this would require both, the land register and the bank account to be in the same blockchain. With a block size of 2 MB to keep the blockchain decentralised, it would be impossible to store all this information. Apart from the fact that cadastral maps, building encumbrance registers, development plans and other files would also have to be stored somewhere.

The blockchain also needs to be permissionless and public as described in chapter 3.2. This is in contradiction to the data protection of the owners and one of the reasons, why e. g. in Germany the land registry office only allows inspections of the land register with a valid justification.

Moreover, the land registry office is interested in having the sole right to write in the land register in order to receive e. g. the land transfer tax. There is no reason why a government should give the land register out of its hands, apart from the fact that even if the property rights are recorded in a blockchain, the enforcement is still done by the government that has a monopoly on the use of force. As already described in chapter 4.3 ownership of a physical property is established by a legal decision and its execution (Wüst and Gervais, 2017). A blockchain has *no advantage* in *connection with physical assets* and cannot completely exclude required actions of a TTP.

Furthermore, in Germany and many other countries, only the land registry office is authorised to make inscriptions in the land register, because it is the only way a legally binding transfer of ownership of a property can take place and the public faith in the land register can be ensured. In order to maintain this in the case of a blockchain application, it must be ensured that only the land registry offices have the authorisation to write new blocks in the network and thus verify real estate transactions. Likewise, it must also be reserved for the land registry offices to grant corresponding read rights to other users, so that access to the land registry data can only be granted if there is an existing legitimate interest. For this reason, theoretically, only a private blockchain managed by the land registry could be used, which basically has no advantages over a conventional central database (Noll, 2019).

In summary blockchain can be a reliable and tamper-proof database and asset register, but *only* for the blockchain's native currency and only, if the currency is valuable enough for the network to have sufficient strong processing power to resist an attack (Ammous, 2016). The DAO incident as described in chapter 5.1 has also shown that even the second largest blockchain after the Bitcoin network is not decentralised enough and does not have enough computing power to be truly immutable. If a blockchain based database can be changed retrospectively by a company or government institution, the question arises why it is not replaced by a more efficient centralised database solution instead. A blockchain uses very expensive mechanisms like PoW to exclude a TTP and it makes no sense that in some use cases a TTP is allowed to overrule the mechanism (Ammous, 2016).

6. Conclusion

It has been explored, why blockchain technology is in general not transferable to use cases other than a peer-to-peer electronic cash and in particular, why the blockchain technology is unlikely to be usefully applied in the construction and real estate industries. For this purpose, basic principles and concepts of the Bitcoin network and its blockchain were explained, which have to be mandatory met by using or adapting the blockchain technology. The main goals of the original Bitcoin Blockchain are decentralisation and the resulting exclusion of a TTP. As a result, the Bitcoin network with its blockchain enables peer-to-peer monetary transactions without the need for (central) banks.

The blockchain itself is a series of linked PoW processes that are the foundation of the decentralisation. Only because of this immensely energy- and cost-intensive process it is possible to ensure that no attacker can take over the network and that decentralisation is maintained.

The prerequisite for this is that the blockchain's own currency has credible monetary properties and thus represents an incentive to perform the PoW. This means that the network can pay for its own security and is not dependent on a TTP. If someone wants to run a blockchain without their own currency instead, there would be no incentive to run PoW and the network would be dependent on the person or company (TTP) paying for it. The use of private blockchains is therefore fundamentally opposed to the original goal of eliminating a TTP. The use of an access-restricted, private blockchain will mainly be advantageous for marketing reasons because a conventional (central) database should be superior to a private blockchain in the most or even in all areas.

In order to maintain decentralisation and give every network participant the possibility to verify ownership independently, the block size has to be limited. It is questionable, if there are any media or file formats, apart from account balances and transactions of a currency, that can be usefully stored in such small blocks. Architectural plan files or even digital building twins exceed the maximum storage capacity of 2 MB by orders of magnitude. Currently, non-fungible tokens (NFTs) are already used to prove ownership of digital image files (jpeg). However, the blockchain only contains a link to a (central) server where the files are stored, which is administered by a TTP.

Real estate is in itself a highly complex asset class that requires a number of different experts to successfully create and operate. Even if it would be possible to exclude e. g. intermediaries, such as real estate agents or notaries, it remains questionable, whether this exclusion is desirable, especially for common people who have no expertise in the construction and real estate industry. At the same time, additional blockchain experts would be needed over a long period of time to make blockchains or smart contracts usable.

Related to blockchain are terms like tokenisation, non-fungible tokens (NFTs), decentralised finance (DeFi) or supposed alternatives to PoW (e. g. Proof-of-Stake (PoS); Proof-of-Authority (PoA)). There are currently around 10,000 different “blockchain projects” (CoinMarketCap, 2022), which makes it impossible to explore all of these projects, but they have the blockchain technology in common and it can be assumed that the described challenges will be difficult to meet completely and meaningfully.

The question that arises before the potential use of a blockchain is, if decentralisation or the exclusion of a TTP is to be achieved at any cost (e. g. high acquisition, implementation and operating costs, efficiency losses) and if an exclusion is at all (technically) possible in the respective use case. As a rule, the use of a centralised database will be significantly more efficient, more secure and more economical.

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Use and Impact of ICT on Cost of Slovak Construction Companies

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Abstract:

Information and communication technologies are a supported tool for cost management in construction. Construction sector is difficult for cost prediction and estimation. The perception of economic sustainability represents an effort for efficiency in the management of cost in construction projects. Within the key performance indicators, the focus is primarily on costs. This research is focused on the use of information and communication technologies for the sustainable cost management of construction projects. The aim of the research is to analyze the use of these technologies and their impact on the cost of construction projects and construction companies in terms of economic sustainability. Research respondents are participants in construction projects (investors, contractors, sub-contractors, and designers). The research uses several quantitative and qualitative methods. The research highlighted the needs and importance of using information and communication technologies and at the same time a positive impact on economic sustainability.

Keywords: *information and communication technology; cost; construction companies*

1. Introduction

Sustainability and the pursuit of the highest degree of sustainability have a positive impact on humanity (Krídlová-Burdová et al., 2020). Efforts to promote sustainable solutions are increasing in every area and in many economies (Vilčeková et al., 2018). However, industry and construction are among the biggest polluters and have a negative impact on the environment Švajlenka and Kozlovská, 2021). In order to deliver the most sustainable solutions possible, it is essential to define the need to look at sustainability and how this sustainability can be achieved (Kozlovksá et al., 2021).

On the one hand, it is the environment and the impact of materials and technologies. Also, in this context, the issue of waste and management is similar. Another view is economic sustainability. Here it is possible to measure through the so-called key performance indicators. Economic sustainability is an important area of sustainability that can significantly achieve efficiency (Bolek and Romanová, 2020). It is in the context of key performance indicators that sustainable results can be achieved. It is performance, productivity, and the effort to reduce costs represent sustainability in the industries (Brucker et al., 2021).

The construction sector is one of the sectors where there is a high scope for sustainability. In the context of economic sustainability, it is essential to define ways to achieve this. Intelligent technologies are one of the solutions. Information and communication technologies (ICT) represent significant opportunities in the pursuit of economic sustainability. The use of different forms of digital tools can contribute to economic sustainability. In the construction sector, this income is not unknown. Efforts to minimize costs and find solutions to achieve this have been the subject of research by several studies (Kravanja et al., 2021; Dasović et al., 2020). New information technologies implemented and used in construction have also been the subject of several studies in Slovakia and abroad (Mayer et al., 2021).

However, to find optimal solutions, there is little research carried out in the construction conditions, the use of intelligent technologies in the context of economic sustainability. Cost as one of the key factors is the subject of research by several studies (Biolek and Hanák, 2019; Hanák et al., 2015). However, comprehensive processing of the impact of the use of ICT on costs in construction companies and construction projects has not yet taken place. Therefore, it is important to assess the cost assessment in terms of the impact on the total costs of the project or company studies (Korytárová and Hromadka, 2010).The second view is the perception of the costs of processes in management, the so-called managing cost. This is a view that, on the one hand, assesses the impact on project costs, on the other hand, provides important information on management processes and management effectiveness. From this point of view, the challenges for the effective management of construction projects and companies can be met, which can represent a key competitive advantage in construction studies (Korytárová et al., 2015).

This also raises basic research questions. What is the impact on costs of using ICT in construction? Furthermore, what impact do these technologies have in terms of management costs and overall costs?

2. Methodology

2.1 Research Aim and Problem Statement

Sustainable construction project management should be based on several pillars. Economic sustainability is one aspect of sustainability. The efficient use of resources (materials, human resources, finances, etc.) should be the goal to achieve sustainability. This puts pressure on efficient cost management as well as the use of all available resources.

Several sources and studies have highlighted the need to use information and communication technologies to achieve a higher degree of economic sustainability. Intelligent solutions in cost management in construction can fulfil the goal, i.e. a higher degree of economic sustainability. Effective cost management in cities should reduce costs (for all available resources and processes such as materials, logistics, use of human resources, etc.) and increase performance indicators (profit, sales, and client satisfaction).

These key performance indicators represent the results of the economic sustainability of construction project management. Therefore, the aim of the research is to analyze the use of information and communication technologies and selected key performance indicators.

2.2 Data Collection and Research Sample

Data collection was provided based on a questionnaire. The questionnaire contained several sections, which had the task of collecting specific data on respondents. The first part of the data collected data on respondents (characteristics of respondents such as company size, a participant in a construction project, activity in construction, the area of construction projects, volume of investment, etc.). Total number of respondents were achieved at 125 numbers.

The second part of the questionnaire obtained research data. Thus, data focused on the research area. This is the rate of use of information and communication technologies for the sustainable management of construction projects.

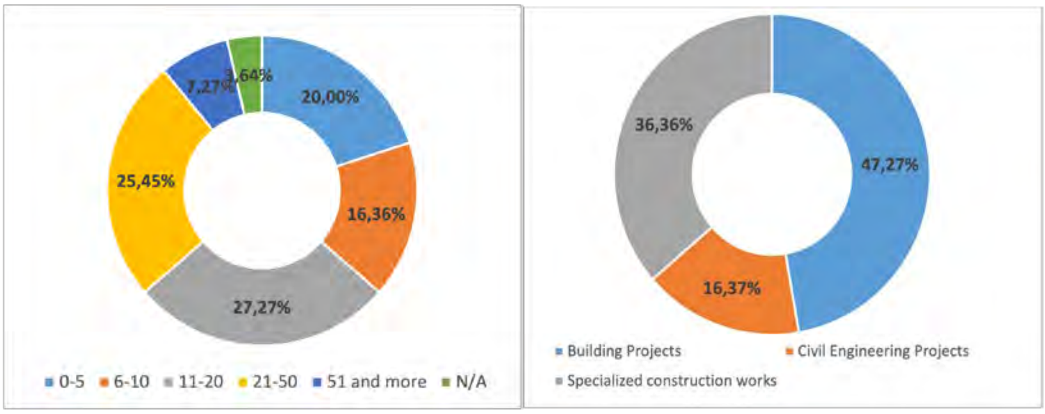

Figure 1. Research sample by (a) respondent experiences in years and (b) the area of construction projects

The research sample was divided based on experience in job position and market presence. Up to 20% of respondents have been on the market for five years. 16.36% of respondents have experience from 6 to 10 years. In addition, respondents (up to 27.27%) have up to 20 years of experience.

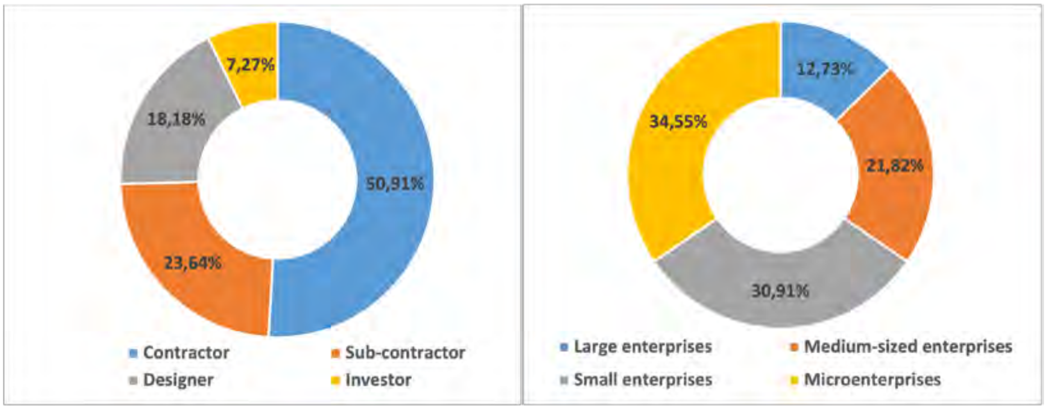

Figure 2. Research sample by (a) participant of construction project and (b) enterprise size

The breakdown of the research sample according to the participant in the construction project and the size of the construction pony is shown in the following figures. Most respondents identified themselves as a contractor. Sub-contractor (50.91% contractor and 23.64% sub-contractor). Investors and designers were also represented.

Large construction companies also took part in the research, namely 12.73%, representing a significant market size.ost subjects were small and micro. This is logical, as these groups make up the largest share of the market.

The research was carried out on the construction market in Slovakia. However, Slovak construction companies were involved in the research, and foreign construction companies that carry out their activities in this area and are part of the Slovak construction market. In addition, Slovakia is a full member of the European Union. For this reason, it is an advantage that this market can, to a large extent, not only be perceived as local but especially with the market in the Czech Republic shared by several business entities that operate in both markets. This reinforces the importance of these research results and the conclusions drawn. Potential influences and the situation in the surrounding European countries are even more significantly affected by economic events in Slovakia.

2.3 Data Processing

Data processing takes place using several validated statistical methods. The research results are largely processed by descriptive statistics, where the results concerning the analysis of the use of information and communication technologies for the sustainable management of construction projects are interpreted. Economic sustainability is perceived as a significant subject of interest and research. The economic sustainability of construction projects is monitored primarily through key performance indicators, which have been quantified in this research.

The Kruskal-Wallis test was designed to determine the significance of the research results. The data collected ranged from 1 to 5 (1 - low utilization rate and 5 - high utilization rate). This division of the scale was also used to identify the impact on key performance indicators in the context of economic sustainability (1 low impact on KPIs and 5 high impact on KPIs). Data processed and interpreted by descriptive statistics were processed using dedicated software. Visual means such as graphs and tables, which provide an overview and trend analysis, are widely used.

3. Results and Discussion

The impact of information and communication technologies on construction costs must be seen from two perspectives. The first view is focused on reducing project management costs (that is, organizational costs, operations, overheads, etc.). The second view is focused on the overall reduction of the construction project (that is, cost savings on the building, building, etc.).

Figure 3 provides an insight into the impact of ICTs on costs. Communication systems in the pre-project phase and DMS systems in the pre-project phase recorded the most significant impact. On the contrary, information systems in the pre-project phase had the most negligible impact in the context of total cost reduction.

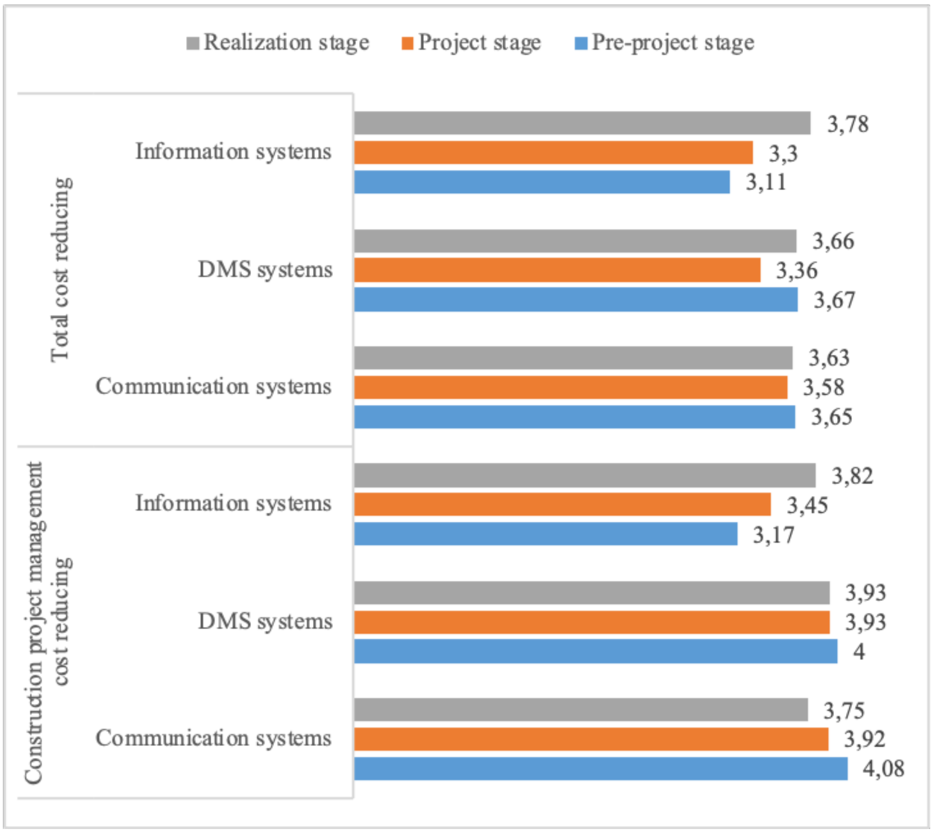

Figure 3. Impact of ICT on sustainable cost management in large enterprises

These results point to the high trend and impact of selected technologies on costs, whether in the perception of costs for the management of construction projects or total costs.

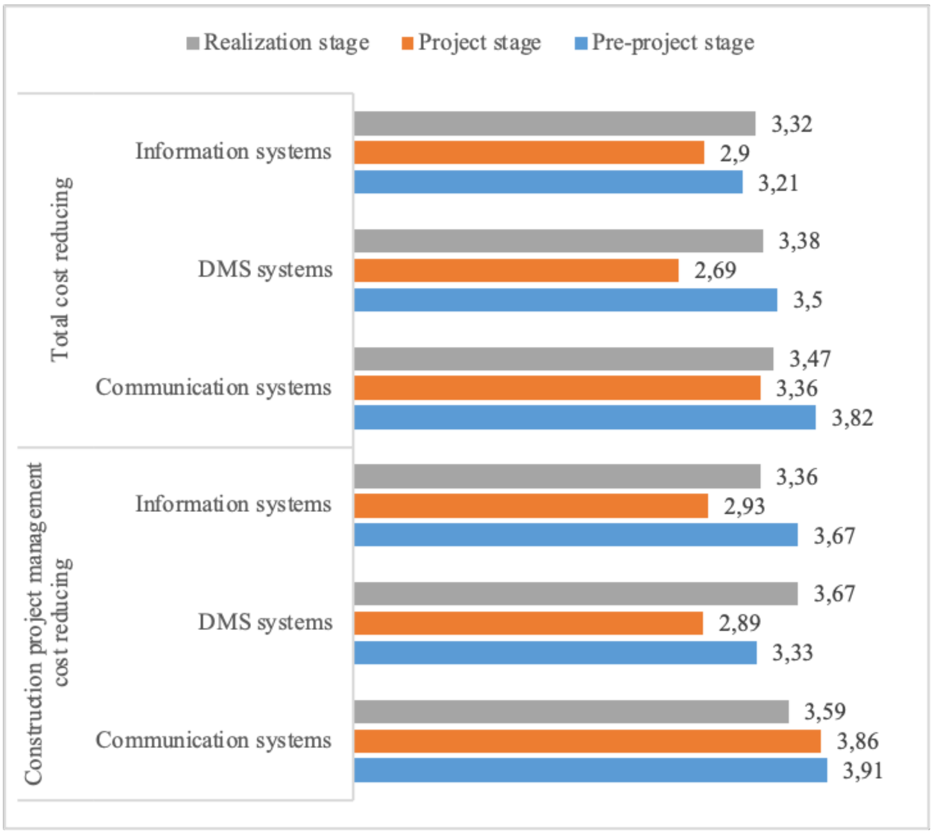

Figure 4. Impact of ICT on sustainable cost management in medium-sized enterprises

Medium-sized companies have also seen a positive impact of the use of these technologies on the cost of construction projects. The use of communication technologies in the pre-project phase was also of the utmost importance for these companies whether it is the total cost of the construction project or also the management costs.

More about these results is discussed in Figure 4. It is possible to see in detail the impact of these technologies on a given type of cost. It is worth mentioning the results of the impact of DMS systems. They recorded lower values in the project phase.

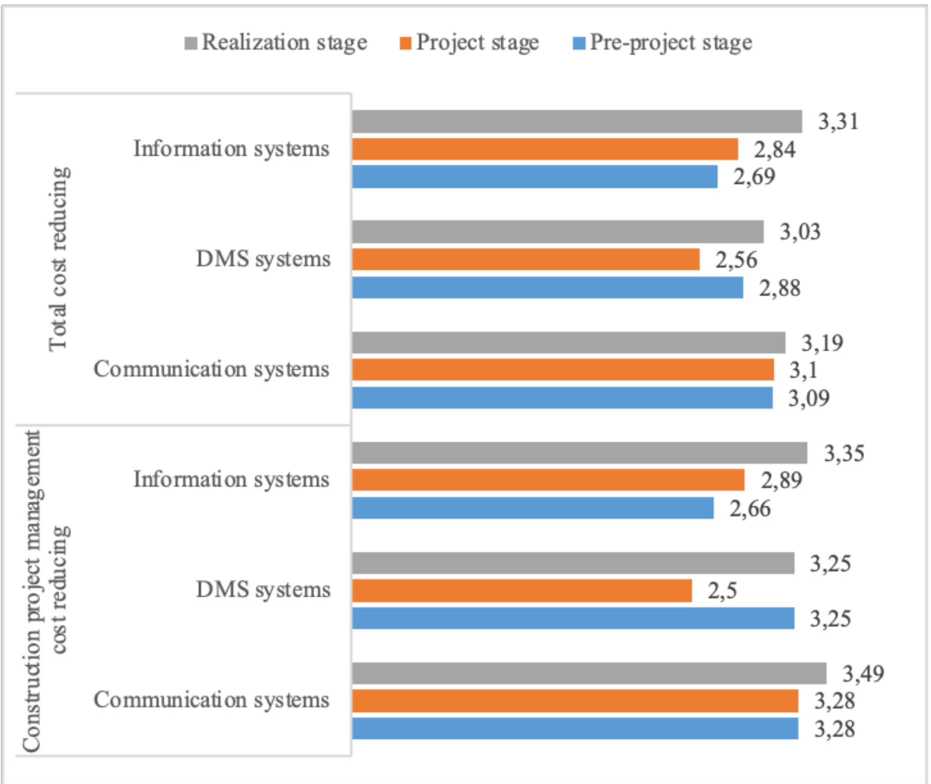

Figure 5. Impact of ICT on sustainable cost management in small enterprises

Small businesses use these technologies to a lesser extent. Overall, these companies spend less money on innovation, including technology. This is likely to result in less impact. Many entities oppose the implementation of information and communication technologies for several reasons. However, the main reason is financial complexity and high acquisition costs.

4. Conclusion

The research focused on the use of information and communication technologies has yielded significant results for practice. Many studies conducted on the benefits of implementing these technologies have suggested that these technologies could impact sustainability in the management of construction projects. In terms of assessing sustainability, it was primarily economic sustainability. Within the key performance indicators, it focused on costs. One of the main findings of the research is that large companies are making greater use of these technologies. The impact on costs is also higher in these companies. Research has also shown the justification for using ICT for the sustainable management of construction projects, as well as in terms of costs.

This research highlighted the importance of ICT solutions and examined the impact on one of the key performance indicators, namely costs. Research has shown that the use of ICT impacts the costs of construction companies and projects. This research has also highlighted the importance and significant impact on the cost of management processes. In general, it can be stated according to individual ICT groups and project phases, when the impact on costs has been shown to be more intense. These results are therefore needed for practice, where they can give an answer, where to use these progressive technologies and at what stage the rate of their use is needed in terms of cost developments.

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This paper presents partial research results of project KEGA 009TUKE-4/2022 “An interactive tool for designing a safe construction site in an immersive virtual reality”.

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NORMENG - Automated Resource Standardization System for Energy-Efficient Construction - Project Progress Report

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Abstract:

This paper presents progressive results of the project named Development of automated resource standardization system for energy-efficient construction (NORMENG) that have been achieved till the half of the three years duration of the project. The research has been directed in two streams. The first one is a study of classification systems for the construction industry (e.g., Uniclass 2015, OmniClass, CoClass, etc.) that enable data structuring in an agreed way and can be used for structuring cost information, specifications, and project information in general. The importance of classification is growing because building projects get more complex and international, but also because project data are based on automated processes. The second stream of research is dealing with construction work progress monitoring with use of two different digitalization tools: Faro Focus LIDAR scanner and drones. To find out the limitations of the rather innovative process of progress monitoring, six different work types were monitored, ranging from masonry works to fine plastering and painting works. The experimentation of the progress monitoring was conducted on a small house specially designed to implement all these six work types and to test out the possibilities and limitations of the progress monitoring technology in these specific conditions. In this paper, the authors will present the initial conclusions of the progress monitoring.

Keywords: *NORMENG; resource standardization; energy-efficient construction; project progress*

1. Introduction

The main purpose of the project NORMENG is to establish and define labor productivity standards in construction, namely those related to energy-efficient construction. Today, when there are numerous examples of long applied and successful models from which construction standards are made, the basic question is how to develop the Croatian standardization model, which corresponds to the institutional, legal and economic frameworks of the environment of the Republic of Croatia and the principles of green building at the same time. The current use of standards when planning new projects and calculating works is at a low level in Croatia. The reason for this lies mostly in the fact that the latest editions of building standards date back to 1986 [4]. Since then, great social and economic changes have taken place, new building materials, work procedures and machines have entered the construction industry. After the completion of the project, it is planned to maintain and adapt the defined standards to new technologies in the future. The detailed description of motivation, context, goals of the project was presented in previously published papers (Ivanišević et al. 2021)

2. Project phases

The project will be to be implemented over a period of 36 months through two phases. The first phase is industrial research lasting 24 months, followed by an experimental development phase lasting additional 12 months.

Industrial research within this project is divided into 3 basic activities. The first activity of industrial research will gather knowledge in the field of development and maintenance of General Technical Conditions and Construction Standards through interviews with significant industry experts both from Croatia and from other members of the EU. Focus groups will also be formed, consisting of public entities in Croatia (Ministries, agencies, local self-government units, educational organizations/institutions, etc.), professional associations (Chamber of Crafts and Commerce, Chamber of civil engineers, etc.), and representatives of the construction industry (contractors, consultants, equipment/technology manufacturers, etc.). This part of the research is trying to formulate the concept of the construction standards model while including components essential for the successful application of environmental goals. A unique methodology for calculating materials, labour, and the amount of machine work for the identified essential works will be developed.

The second phase of industrial research envisages the analysis of existing technologies and trends in the field of standardization of energy-efficient construction. Analytical studies of new technologies for the implementation of works related to environmentally sustainable construction will be conducted, which would result in the formulation of a conceptual form of a model for the standardization of energy-efficient construction. Standardization of the procedure is the key to the comprehensive applicability of standards, and at this stage of industrial research, innovation is expected in defining the standardization procedure using new technologies for measuring quantities of work performed in chosen unit of time.

In the third phase of the industrial research, the validation of the standardization model will be applied using modern technologies set in the earlier phases of industrial research. The formed concept of standards for environmentally sustainable construction, as well as the concept of standardization with new technologies, are validated in this phase of the project on individual works in laboratory conditions using the collected data from the test site. A test site will be established where previously defined activities will be monitored and an attempt will be made to prove or deny their accuracy.

After the completion of the industrial research within this project, an experimental development lasting 12 months is envisaged. Experimental development is divided into two basic phases. After the methodology of standard development has been defined in industrial research and has been experimentally proven, in the first phase of experimental development, standards will be validated and demonstrated in the relevant environment. The goal of this first phase is to validate the methodology of standard development in the operational environment and demonstrate its functioning in the real environment. Resources required to carry out this activity include the equipment such as photogrammetry equipment and software, laser scanning equipment and software along with other equipment for processing the collected data. These resources will be used on construction sites to collect and process the data needed to develop standards, in a manner defined in the activities of industrial research. The results obtained from data processing will be used to develop standards and demonstrate the developed technology in a real environment.

In the last phase of the research, the digitalization of the database on standards and the development of a software solution will be carried out. For developed standards to be applicable in the economy, it is necessary to digitalize the previously created database of standards and create a user interface of a software tool that would enable the application of standards in the operational environment. The goal of this project activity is to prove the applicability of the developed standards in the operational environment, especially in the application of real examples in the construction industry.

Two important parts of research has been implemented so far and their main results are presented in continuous.

3. Classification systems for the construction industry

Classification systems for the construction industry enable data structuring in an agreed way and can be used for structuring cost information, specifications, and project information in general (Lou and Goulding, 2008). Furthermore, the purpose of classification systems is to provide a system of grouping, organization and indexing of project data which means that project data can be organized in predefined levels (e.g., building type, space type, entity type, element type, system type, product type, role type, activity type, etc.). Example of grouping levels (ventilation systems categories) provided by the Uniclass 2015 classification system is shown in the Figure 1.

Title	Table	Code
Ventilation and air conditioning systems	Systems	Ss_65
Ventilation systems	Systems	Ss_65_40
Smoke extract and control systems	Systems	Ss_65_40_80
General space ventilation systems	Systems	Ss_65_40_33
Hazardous processes ventilation systems	Systems	Ss_65_60_55
Fume extract systems	Systems	Ss_65_40_32

Figure 1. Uniclass 2015 classification system – grouping levels (Uniclass, 2022)

There are many national classification systems for the construction industry which are listed below (BIMAXCON, 2022; Lou and Goulding, 2008; Cerezo-Narváez et al., 2020; OmniClass, 2022):

- Uniclass 2015 (UK)
- OmniClass (US)
- MasterFormat (US, Canada)
- UniFormat (US, Canada)
- SfB (Sweden)
- CoClass (Sweden)

- Cuneco Classification System - CCS (Denmark)
- TALO 2000 (Finland)
- NS 3451 and TFM (Norway)
- Japanese Construction Classification System (Japan)

The importance of classification is growing because building projects get more complex and international. Therefore, a lot of project information need to be exchanged between various parties during design, construction, and operating phases. As previously sated, classification systems within the construction industry have been predominantly based on national needs, but for international application classification systems must be founded on a neutral conceptual framework (Lou and Goulding, 2008). International standards which define the development of classification systems are for example ISO (International Organization for Standardization) standards (ISO 81346-12:2018; ISO 22274:2013; ISO 704:2009; ISO 1087-1:2000; ISO 1087-2:2000, etc.). Finally, Building Information Modeling (BIM) concept provide numerous possibilities of international data structuring due to the standards for classifying BIM data: buildingSMART Industry Foundation Classes (IFC) – data model standard; buildingSMART Data Dictionary (bSDD) – library of objects and their attributes; ISO 12006-2 – international framework for classification; ISO 12006-3 – international framework for object-oriented information (BIMAXON, 2022; buildingSMART, 2022).

4. Progress monitoring on a test object

The second stream of research was aimed at identifying technological solutions that could capture the progress of construction works and estimate constructed volumes to enable capturing the data needed to assess construction norms. The progress tracking was tested out on six different work types: masonry works, plastering works, façade works, drywall works, carpentry works, roof decking works. For testing purposes, a house was designed and constructed. The house was designed (Figure 2). purposefully to accommodate all the previously mentioned works while at the same time representing almost realistic on-site situations.

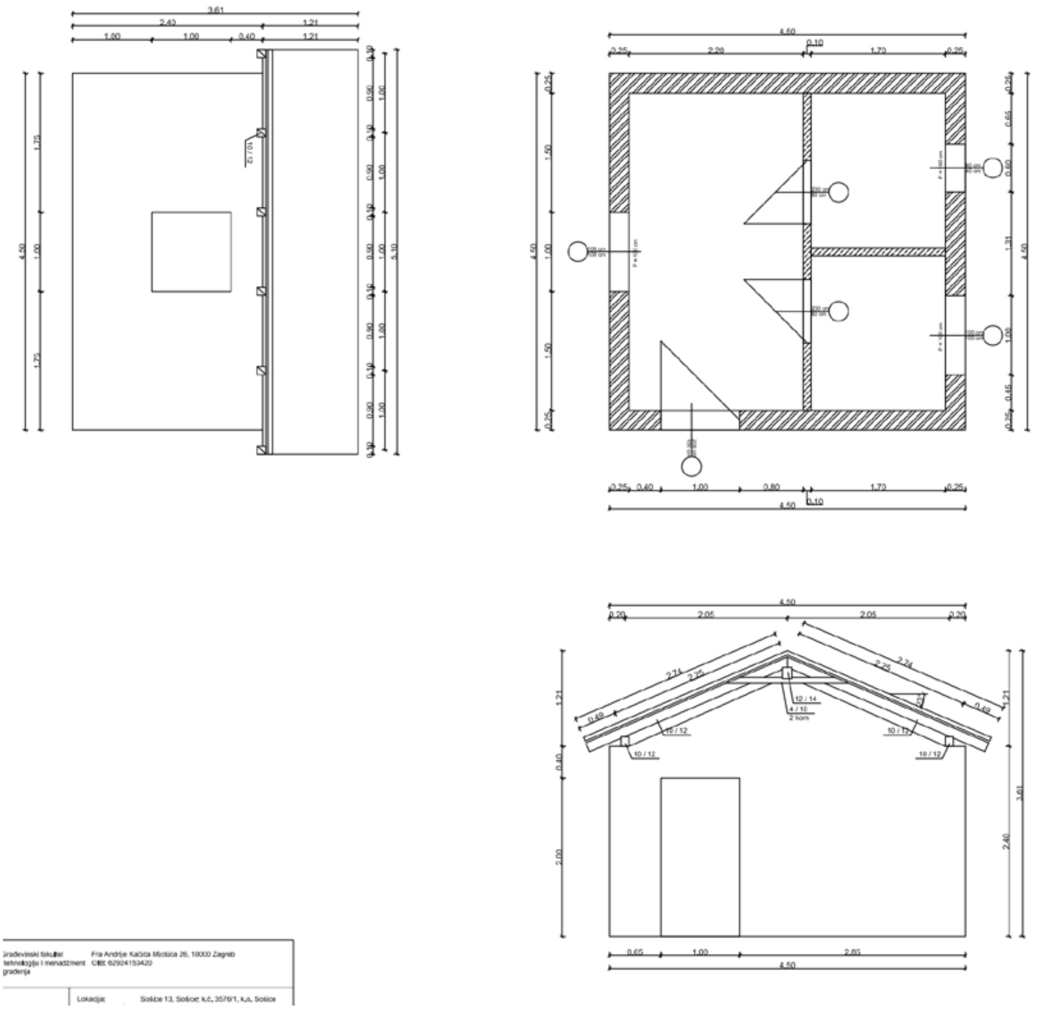

Figure 2. House for testing purposes

For the progress monitoring process, a number of different tools of digitalization were used (Figure 3):

- FARO Focus M - LIDAR scanner
- DJI Matrice 300 RTK with Zenmuse P1 camera – UAS with a high-definition camera (maximum take-off weight 9kg)
- DJI Inspire 2 with Zenmuse X7 camera – UAS with a high-definition camera (maximum take-off weight 4.25 kg)
- 4 DJI Air 2s camera drones - UAS (maximum take-off weight 0.59 kg)
- DJI Osmo Action - handheld camera

Figure 3. Video frame was taken with a UAS

The construction process monitoring was done by continuous work process recording (DJI Osmo Action) and process recording at certain construction states (situation capturing). The situation capturing process was organized at least three times a day, when workers had to stop all work, and the situation capturing would start.

In the process of experimenting with the situation-capturing process, we tested out different technologies and approaches (Figure 4):

- Situation capturing while workers were active with UAS
- Situation capturing with workers evacuated from the construction site with UAS and LIDAR
- Situation capturing with a handheld camera

Figure 4. Picture of the house at the test site

The initial situation capturing process led to further conclusions in regard to the technology that was used:

- DJI Matrice 300 – perfect for situation tracking from higher altitudes outside of the sight and hearing of workers. Due to its long flight time capability, it can be used for active tracking of on-site activities
- DJI Inspire 2 – perfect for high-altitude continuous situation recording (video). Not good for high-detailed photogrammetry or continuous work progress tracking.
- DJI Air 2s – good for closeups, low-altitude photogrammetry and continuous progress tracking; however, it is limited by its short flight time.
- Handheld cameras – situation capturing is possible, still, perfect results cannot be expected due to its lack of position tracking. Here a good reference marking would be needed which is next to impossible in cases of an active building site.

5. Conclusions

The results of the project are intended to enable a more precise calculation of the usage of all necessary resources, which, in addition to rationalizing the use of resources and reducing waste, also brings benefits in the form of reducing disputes over material consumption. In addition, the establishment of a unique standardization methodology in energy-efficient construction would significantly facilitate both investors and contractors in defining all requirements and costs and encouraged them to focus on "green building", which would contribute to the further recovery of the construction/economy, as well as solving climate challenges. Greater activity in the construction sector would also enable business development, including the creation of new jobs, both in the construction sector and in related activities. Not to forget, the results of the project would bring significant improvement in the education of civil engineers, giving them updated knowledge they need in order to successfully apply green building techniques once they graduate.

The application of new technologies for the development of modern standards of energy-efficient construction would certainly contribute to the attractiveness of the construction sector as a profession, which could be a positive impact on attracting labour to a sector where it is currently lacking.

Acknowledgements

In this paper, we would like to show our gratitude to the European Union for their financial help for the project KK.01.1.1.07.0057 Development of automated resource standardization system for energy-efficient construction (NORMENG) through the European Regional Development Fund. The content of the publication is the sole responsibility of The University of Zagreb Faculty of Civil Engineering.

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The Inspirational Emotional Infection for Managing Renovation Projects

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Abstract:

Inspirational emotional infection is considered a social and psychological mechanism of transferring the mental mood of the manager to the project team and stakeholders of the project's success. Inspirational emotional impact in the face of project implementation and the inclusion of the team members in certain mental states have an impact on the effectiveness and efficiency of renovation project management. The main objective of inspirational emotional infection analyses is to educate and creates the organization of new behaviour in adverse, deadly and aggressive external conditions of the manager or team. In times of global crisis and War in Ukraine, the emotional competencies of the renovation project manager's behaviour and his inspirational infection with the project team are exacerbated by internal and external uncertainty. The inspirational emotional infection model is based on an understanding of the life cycle of the project manager of renovative projects and programs. Emotions are considered in content, reflecting the various aspects and meanings that caused them.

Keywords: *innovation project; emotion intelligence; emotional infection; competence; inspirational intuition*

1. Introduction

Creatively, innovative thinking is the most valuable, open-ended part of stakeholders' thinking that manifests itself in the form of certain inspirational emotions (Azarov, et al., 2011). The health of innovative thinking is a delicate balance between the order and the chaos of stakeholder behaviour. Behaviour is often manifested through a variety of emotions (Brackett, 2011). Scientific advances in this field are limited and far from complete, but at the same time, several common features inherent in this process and the behaviour of renovative project managers can be distinguished (Bushuyev, Kozyr, Rusan, 2020). Mission (goals structure) is defined as the result to which the activities of managers are directed. The goals are arranged in a certain sequence, which regulates the rational and emotional activities of the manager (Bushuyev, et al., 2020). As soon as one of them is reached, a new one arises and so on until the final goal is reached. Each step towards the main goal has a local purpose. Therefore, thinking can rationally organize or profile the mission (P2M. 2017). Such an organization serves to manage actions in a renovation project. Many goals and stages of their achievement are profiled in the form of a graph having the structure of a tree. The behaviour of a modern project manager is organized in such a way that thinking is the cause, and action is the consequence (think first, then do it), though it is often the other way around (Goleman, 2010). The peculiarity and a priori uncertainty of the renovation goal is its new quality. In turn, the renovative projects' qualities of the purpose of the concept are relative and depend on subjective evaluation, experience, erudition, emotional intelligence, benevolence of expertise, and public recognition (Goleman, 2013).

Let’s look at the situation in Ukraine after 150 days of the Russia-Ukraine war in the 2022 year.

Since the beginning of Russia’s war against Ukraine, at least 388 enterprises, 18 civilian airports, 779 medical institutions, 1,371 educational institutions, 690 kindergartens, 23 shopping centres, 28 oil depots, 105,200 private cars, 563 cultural and religious facilities have been damaged, destroyed or seized. At the same time, as of July 5, 43 bridges have already been restored and 941 km of state roads have been demined, according to the Ministry of Infrastructure of Ukraine.

The total amount of documented damages is $95.5 billion, minimum recovery needed for destroyed assets — is $165.1 billion.

According to the government’s estimates presented in Lugano, the total cost of rebuilding Ukraine is approximately $750 billion. This amount includes not only the cost of rebuilding the destroyed facilities but also the need for fiscal support, modernization, and strengthening capacity of key economic sectors, as well as assistance to resume business and enterprise activities.

Consider renovation projects as projects for the rebuilding or restoration of construction projects based on innovative technologies and materials.

The purpose of our research concerns modelling the inspirational emotional society infection for managing renovation and rebuilding projects after the Russian-Ukraine war in the 2022 year.

2. The Inspirational Emotional Infection of Renovation Projects Team

Managing renovation project very often appear to have inspirational emotional resonance. The technique of emotional resonance can be defined as a way of creating a certain mood among wide virtual team members while transmitting useless information (Rusan et al., 2017). Emotional resonance allows you to remove the psychological defences that the virtual team member builds on a mental space, deliberately trying to protect himself from useless (propaganda or advertising) brainwashing. Relevant techniques have been known since ancient times. They are based on the phenomenon of social induction (inspirational emotional infection). The fact is that the emotions and feelings we experience are largely social phenomena (Decety, 2011). They can spread like an epidemic, sometimes infecting tens and hundreds of thousands of people and causing the masses to "resonate" in unison. The virtual teams are social creatures and easily perceive the feelings arising from others. This is visible at the level of interpersonal relationships. Everyone knows what it means to "spoil the mood" of a loved one and how easy it can sometimes be done. The effect of inspirational emotional infection manifests itself especially strongly in the crowd - a situational set of people who are not connected by a conscious goal (Obradovic et al., 2018). The crowd is a property of a virtual team as the social community, characterized by the similarity of the emotional state of its members. In the crowd there is a mutual infection of emotions and, as a result, their intensification. The nature of the mass emotional infection is almost unstudied. One of the interesting hypotheses states that the main role in this is played by the appearance of resonant oscillations in the structure of electromagnetic fields formed by the human body (Mayer, et. al. 2008).

The mechanism of human behaviour in a crowd is described in many sources, they all coincide in the fact that a virtual team member, becoming part of the masses, falls under the power of passions (Sargwelladze, 2009). Typical signs of human behaviour in a crowd are the prevalence of situational feelings (moods), loss of intelligence, responsibility, hypertrophic suggestibility, and easy controllability. These conditions can be enhanced by various means. The necessary moods are caused by the appropriate external environment, a certain time of day, lighting, light stimulants, various theatrical forms, music, songs, etc. In psychology, there is a special term - fascination, which denotes the conditions for increasing the efficiency of perceived material through the use of related background effects. Most often, fascination is used in theatrical performances, game and show programs, political and religious (cult) events, etc. - to infect people in the crowd with a special emotional state. Against this background, the relevant information is transmitted, and we must strive to ensure that it is not too much (Burns, 2004).

In the modern world, the inspirational emotions we experience are largely the result of induction caused by the mass media. Creating emotional resonance is one of the main tasks of most informational messages and entertainment shows. The media always try to evoke strong emotions in a wide audience, and if necessary, they bring these emotions to a psychological shock (Decety, Ickes, 2011). A simple example: pay attention to those intonations with which radio or television presenters read out information about events in the country and the world to us. When it comes to tragic events (catastrophe, war, terrorist act), intonations are usually filled with noble sorrow or indignation towards the perpetrators. If, for example, after this, there is a message about the next meeting of the head of state with miners (pilots, teachers, doctors), the manager will notice to the virtual team how the on-TV screen instantly transforms and "constructive optimism" and confidence in a happy future begin to appear clearly in her voice nation (Jakobony, 2011). This technique is called "emotional adjustment to the situation." In such a simple way, you can form the emotional attitude of a mass audience to a particular event (Krysko, 2006).

The result is the following classification of the inspirational emotional process:

- inspirational emotions are longer and less intense than effects, emotional processes that reflect the subjective meaning of situations, but not of specific objects in themselves;
- affects - short-term and intense emotional processes, accompanied by pronounced motor manifestations and changes in the work of internal organs;
- feelings are longer and less intense than effects, inspirational emotional processes that reflect the subjective meaning of specific objects. For example, hatred moods are quite prolonged emotional processes of low intensity.

A negative impact is blindly following someone else's mood and reactions, for example, when a "breeding ground" of gossip and negativity appears in the team, which changes the mood of the masses, causing anxiety and distrust of colleagues, which, of course, affects labour efficiency. Unconsciously "mirroring" the emotions of other people, we begin to feel the same emotions as they are (Verenych et al., 2019).

The positive effect is associated with self-control. We try to manage our own emotions, notice changes and control our condition. For example, a confident leader can easily convey an optimistic attitude to his team. Here for the manager, it is important to give people a positive charge and set up and motivate them to succeed in their work.

Interestingly, in this case, infection occurs without the participation of non-verbal signals. However, the inability to see the poses and facial expressions, as well as to hear the voice of other people, is compensated by new means of transmitting emotions that are used when communicating with the virtual team on the Internet. This is a certain style (you know exactly a certain number of people who abuse capsules and punctuation marks), typical mistakes that people make when they are nervous and, in a hurry, as well as the specifics of using emoticons and stickers. This area is still waiting for its researchers - we give an idea.

Inspirational emotional infection is a socio-psychological mechanism of transmitting the mental attitude to other people from one person or group of people, emotional impact in conditions of direct contact and the inclusion of the virtual team in certain mental states.

Inspirational emotional infestation is a social and psychological mechanism of transfer of mental mood to other people from one person or group of people, emotional influence in the conditions of direct contact and inclusion of a person in certain mental states.

Inspirational emotional contamination occurs in large open spaces, especially in virtual communities, for example, in a crowd that can spread certain emotional states quickly. Most often, these conditions can be markedly enhanced by multiple reflections of the virtual team in the chain reaction scheme. However, unlike cognitive chain reactions, complementary emotional transmission is less conscious and more automatic.

Inspirational emotions are different in content, reflecting different aspects of the significance of their situations. To apply the psychophysiological formula for assessing the impact of the inspirational emotional state of the stakeholders of renovative projects, we transform these influences into a competent complementary dream model for managing renovative projects (Todorovic et al., 2015).

Not only members of the project team, but also other participants involved in the project in one way or another, including service companies, agencies responsible for forming a temporary staff, etc. - are directly affected by the project product, or the project implementation process. The stakeholder is, therefore, a generic term that defines all institutions, companies and individuals who are directly or indirectly affected by the project (ICB 4, 2015).

A project manager is a mission-oriented professional with the necessary authority to manage and integrate the project; its role is to detail the mission of the project on goals and objectives, formulate a complementary strategy for its implementation, and form a virtual project team consisting of experienced professionals to perform work on a project that has certain limitations and conditions for implementation (Bushuyev, Wagner, 2014).

The skills, models, and management techniques used in a project depend on whether conventional management methods can be used, or for maximum efficiency and effectiveness teams of Agile project management areas need to be applied (IPMA ICB 4, 2018).

3. Driving inspirational emotion by Entrepreneurial energy. Conceptual model

Convergence in science leads us to the idea of using the provisions of thermodynamics - the presence of energy in systems of various natures in the practice of project management. Considering the energy of the organization as resources used in projects that are valued in terms of money.

Considering the analogies of thermodynamic models, such a specific type of energy as "entrepreneurial energy" is usually singled out. This energy is defined as the energy of the labour resources of projects. This is a special type of energy that affects the success of the project, is valued in terms of money and plays a key role in the efficiency of the organization's energy exchange with the external environment in the implementation of projects and programs. Today, project managers successfully use methods for managing the time, cost and quality of projects based on well-known methodologies and standards (Azarov et al. 2012). At the same time, models associated with a "special type of energy" - the energy of labour resources or entrepreneurial energy are practically not developed and are not used. Within these models, a significant role is played by the motivation of the project team, the intuition of managers and leadership, which are multiplied by methods of inspiring behaviour.

Entrepreneurial energy provides a certain level of interaction between the organization and the external environment, forming the flows of incoming and outgoing energy E^{in}, E^{ex} (Fig. 1). The result of the interaction of the organization and the external environment is the effective interaction of the external environment and the external structure of the organization. This takes into account not only a certain ratio of input and output entrepreneurial energy E^{in}, E^{ex} but also the level of information entropy H, which reflects the degree of uncertainty in the results of the organization's activities. The lower the level of entropy H, the higher the level of entrepreneurial energy of the organization. The state of the organization in terms of its interaction with the external environment, the degree of control over it, as well as the cost of resources to maintain the organization, is estimated by the entropy S. Conceptual model of the formation of entrepreneurial energy based on enthalpy presented on Figure 1.

The multidimensionality of systems, the state of which is estimated by entropy and enthalpy, is described by the Gibbs-Helmholtz equation. This equation is the most appropriate formalization for organizations. Firstly, it does not use such categories as volume, pressure, and mass of particles, which are present in other equations for enthalpy. Secondly, this equation relates entropy and enthalpy.

When evaluating the states of the system, it is not the value of the estimated indicator that is important, but its change [6]. According to the Gibbs-Helmholtz equation, energy, enthalpy and entropy are related as follows:

$$\Delta G = \Delta I - T\Delta S, \tag{1}$$

where ΔI is the change in enthalpy, ΔG is the change in energy, T is the temperature, ΔS is the change in entropy.

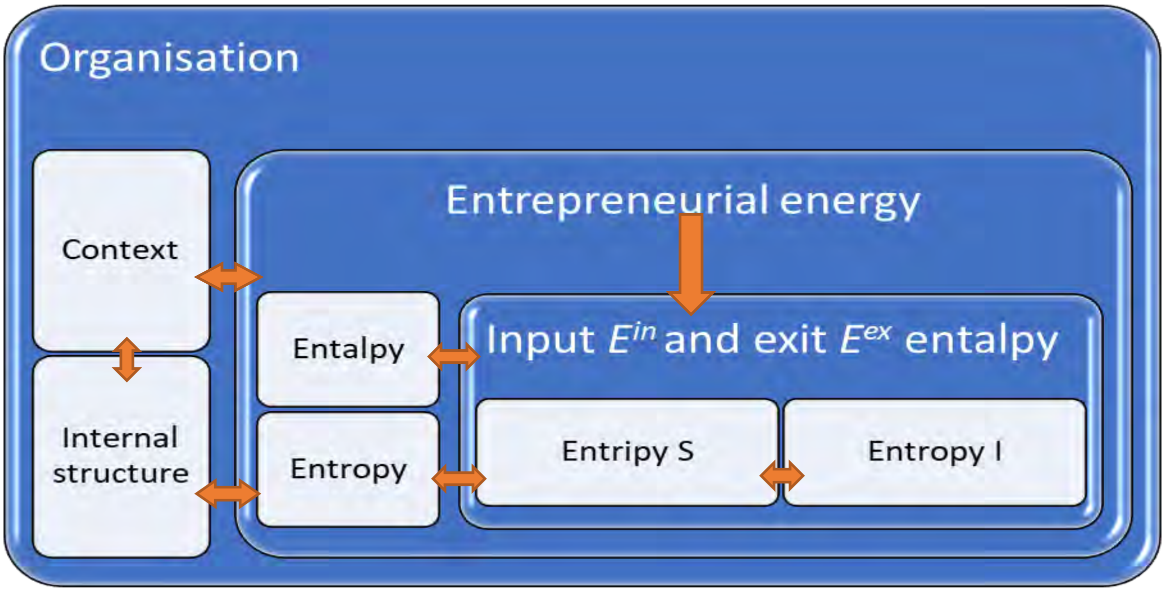

Figure 1. Conceptual model of the formation of entrepreneurial energy based on enthalpy

From expression (1) follows:

$$\Delta I = \Delta G + T\Delta S. \tag{2}$$

In this case, the energy of the organization is an analogue of the Gibbs energy (free energy, Gibbs potential, or thermodynamic potential).

From expression (2) it follows that a certain amount of heat of the thermodynamic system is spent on increasing the entropy, this part of the energy is lost to perform useful work, it is sometimes called "bound energy". Another part of the heat can be used to do "useful" work, so Gibbs's energy is often also called free energy.

Enthalpy, therefore, is an assessment of the energy potential of an organization, taking into account information entropy and organizational entropy in a thermodynamic context.

Within the framework of the management concept under consideration (Bondar *et al.*, 2021):

$$\Delta G = E^{in} - E^{ex}, \tag{3}$$

where, E^{in}, E^{ex} respectively, incoming and outgoing energy - the inflow of resources and their costs in the course of the organization's activities.

Gibbs energy shows how much of the total internal energy of a thermodynamic system is used to do "work", so in terms of the organization and its energy, Gibbs energy can be interpreted as the "realized energy entrepreneurial potential" of the organization, while enthalpy is the "full energy potential" of the organization.

To understand the essence of the enthalpy of an organization, let us analyze (2) taking into account the fact that in [3] following expression for temperature was proposed, which determines its energy efficiency:

$$T = \frac{\mu}{H}, \tag{4}$$

where μ is the relative energy efficiency of the organization (compared to a certain reference value), H is the information entropy.

It follows from this that (2) will take the form:

$$\Delta I = E^{in} - E^{ex} + \frac{\mu}{H}\Delta S. \tag{5}$$

In this case, μ H determining the entropy [3] ΔS depends on the change in energy efficiency and information entropy. In expression (2) $\frac{\mu}{H}$ is considered as the achieved value of "temperature".

If in thermodynamics absolute values of changes in energy, entropy and enthalpy are of interest for assessing the state of a system, then relative units are necessary from the point of view of organizations and the use of information in management.

It is proposed to use the following indicators:

$$P_{\Delta G} = \frac{\Delta G}{\Delta I} = \frac{E^{in} - E^{ex}}{\Delta I} = \frac{E^{in} - E^{ex}}{E^{in} - E^{ex} + \frac{\mu}{H}\Delta S}, \tag{6}$$

$$P_{\Delta S} = \frac{\frac{\mu}{H}\Delta S}{\Delta I} = \frac{\frac{\mu}{H}\Delta S}{E^{in} - E^{ex} + \frac{\mu}{H}\Delta S}, \tag{7}$$

These figures add up to one. They reflect the shares of the realized energy potential $P_{\Delta G}$ and dissipation (its scattering) $P_{\Delta S}$, respectively. At the same time, the higher the value $P_{\Delta G}$, the more successfully the organization realizes its energy entrepreneurial potential.

Consider the energy entrepreneurial potential as a driver of inspiring emotions. In the conditions of war in Ukraine, inspiring emotions have a decisive influence on the success or failure of projects and programs.

Let's determine benchmark B of the level of realized energy entrepreneurial potential $P_{\Delta G}$, at which inspiring emotions begin to form in the team of project managers and the organization. At the same time, it is necessary to take into account the level of dissipation $P_{\Delta S}$, which leads to the dissipation of entrepreneurial potential during the implementation of projects, and, consequently, to a decrease in the level of inspiring emotions and the risks of unsuccessful completion of the project. The ratio $P_{\Delta G}$ and $P_{\Delta S}$ relative to benchmark B allows you to determine the sign of the inspiring emotion of the project team.

Define research hypothesis.

1. Success of the project depends on the positive inspirational emotion of stockholders.
2. Life cycle of the project needs to be taken into account.

In this case, the project success formula is presented below.

Project success is driven by positive Inspirational Emotion through the Project life cycle based on Renovation leadership, Motivation and Competencies of the project team for Creating Project Value

Let’s look at Inspirational emotion through Motivation and the Project life cycle.

The motivation of the team at the beginning of the project is most affected by the inspirational emotional intelligence of employees, Renovation leadership and the empathy of the stakeholders (Barling et al., 1996).

Stage 1 - little experience, lots of enthusiasm (low skill, high motivation). This may be a young specialist who got his first job; a person who has decided to try himself in a new profession or a professional who has been promoted to a managerial position. In general, any of the options when a person just came to a new place is very keen to succeed but still does not understand how to do it.

Stage 2 is the first disappointment (low skill, low motivation). At this stage, our expert comes to the understanding that everything is not as easy as it seemed at first. He makes the first mistakes, succeeds at once, and, most importantly, comes the understanding that the path to the summit is long enough and not at all as simple as it seemed at first.

Stage 3 - natural growth (skills are increasing, motivation is different). If a specialist manages to overcome the previous stage, he enters the path of professional growth. It is already clear what exactly needs to be done for development, it is also clear that the path to success lies through a long methodological work. This stage is usually quite long, with its black and white stripes, so there is not one level of motivation in it, the only thing that can be said is usually enough to keep moving forward.

Stage 4 - competent specialist (high skill, strong motivation). At this stage, the specialist goes to the competence plateau and can begin to perform tasks autonomously (without a manager), gradually expanding his sphere of responsibility and helping beginners at work. Ideally, having worked for some time in this mode and having prepared a replacement, the employee goes to the raise and returns to the first stage, starting a new turn of his career spiral. In real life, unfortunately, it often happens not so. New posts are not always available, and teaching yourself a worthy replacement does not allow for the absence of any candidates for this post, so the next stage comes.

Stage 5 is a very competent specialist. This condition is described by the English word "overqualified" and indicates a significant discrepancy in the competence of the specialist and the needs of his office. The state is characterized by a constant decrease in motivation, due to the lack of a positive connection from the implementation of complex, interesting tasks. After some time, the decline in motivation leads to disappointment from work and shifting the priority from work to something else (hobbies, families, and outsourced projects). Typical external attributes: a person starts to work strictly on schedule, and at a meeting more speaks not about his work, but about something that took her place in the system of priorities.

Consider the model "Framework for Strategic Sustainable Development (FSSD)" (Broman, Robert, 2017). The general method of FSSD development allows for the development of rational framework models (frameworks) for the formation of competencies of sustainable strategic renovation.

The model includes five steps of application. It focuses on the system, goals, strategies, actions and tools and indicators.

The model helps organizations to deeply understand and place themselves in the context of the global challenge of sustainability, as well as strategically move towards sustainable development, i.e. gradually reduce their negative impact on environmental and social systems as a whole, while strengthening their organization through innovative opportunities, including new business models, exploring new markets and gaining new market shares, and by reducing risks and operating costs. In particular, FSSD helps to better manage system boundaries and trade-offs, enables the modelling and evaluation of sustainable capacity for different materials and practices before investments are made, and offers the possibility of more effective cooperation between disciplines and sectors. The FSSD model helps to prevent losses, even from unknown problems, and last but not least, to manage the selection, development and combination of additional methods, tools and other forms of support, which allows increasing their usefulness for strategic sustainable development.

The model is based on the "creativity pyramid" built based on the liner, literary and holistic vision technic is shown in Figure 2.

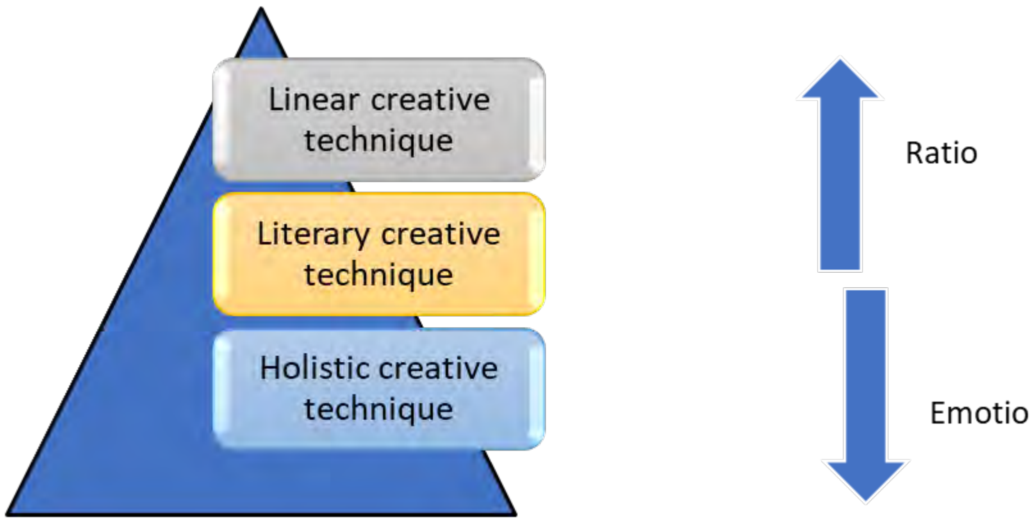

Figure 2. Creativity Pyramid built on three levels view

In this case, the model from the top of the pyramid forms decisions based on "ratio", and at the holistic level, decisions are mainly formed based on "emotion".

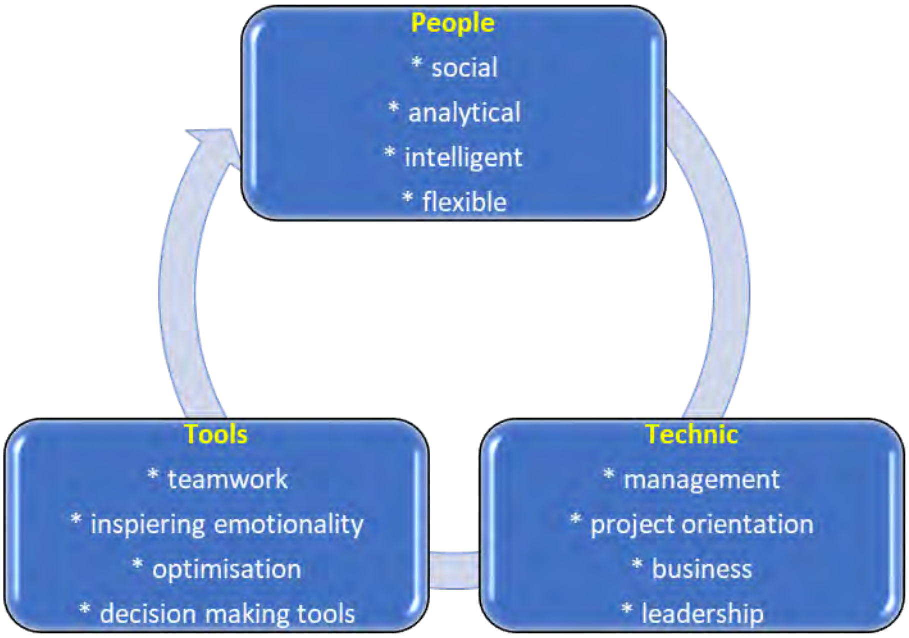

Figure 3. Model of competence groups of strategic sustainable renovation

The driver of the model is intuition built on creativity (Bushuyev et al., 2017). At the same time, the authors (Broman, Robert, 2017) built a process model that connects personal competencies, intelligence and creativity. There are four groups of competencies in the model - social, analytical, intellectual and variable (Figure 3).

Consider the model of key competencies for building Inspiring Emotions within the framework of Strategic Sustainable Renovation (SSR). To assess inspiring emotions on the SSR model, an experiment was conducted on one of the examples of the reconstruction of a destroyed object in the city of Bucha, Kyiv region. The assessment team consisted of 10 specialists in the field of reconstruction of construction sites. The team used the unified IPMA Delta and OCB model (Bushuyev, Wagner, 2014) for competency assessments:

1. For this, questionnaires were developed for a set of competencies proposed by the SSR model.

2. During the benchmarking process, the team determined a score level of six, which affects the inspiring emotion sign with a minus score below six and a plus sign above six.

3. In addition to evaluating the benchmark, the levels of influence of inspiring emotions on the success of the project were assessed.

The model is given in the Table. 1.

Table 1. Model of key competencies for Inspiring Emotion for Strategic Sustainable Renovation (SSR)

№	Group/competence	Benchmark level of inspiring emotion to project success (from 1 to 10)	The level of influence on inspiring emotion (from 1 to 10)
1	**People**	6	5
2	Social	6	5
3	Analytical	6	7
4	Intelligence	6	5
5	Flexible	6	4
6	**Technique**	6	8
7	Management	6	8
8	Project orientation	6	9
9	Business	6	8
10	Leadership	6	7
11	**Tools**	6	9
12	Teamwork	6	9
13	Inspiring emotionality	6	8
14	Optimization	6	9
15	Decision making	6	8

The model of key competencies for inspiring emotion within the framework of the framework for Strategic Sustainable Renovation (SSR) is presented in Figure 4.

The analysis of the results obtained showed the weaknesses of teamwork in managing the reconstruction project. These weaknesses are concentrated in the People group. These are Social, Analytical and Intellectual competencies, which are rated with a value of five and Flexibility is rated with a value of four.

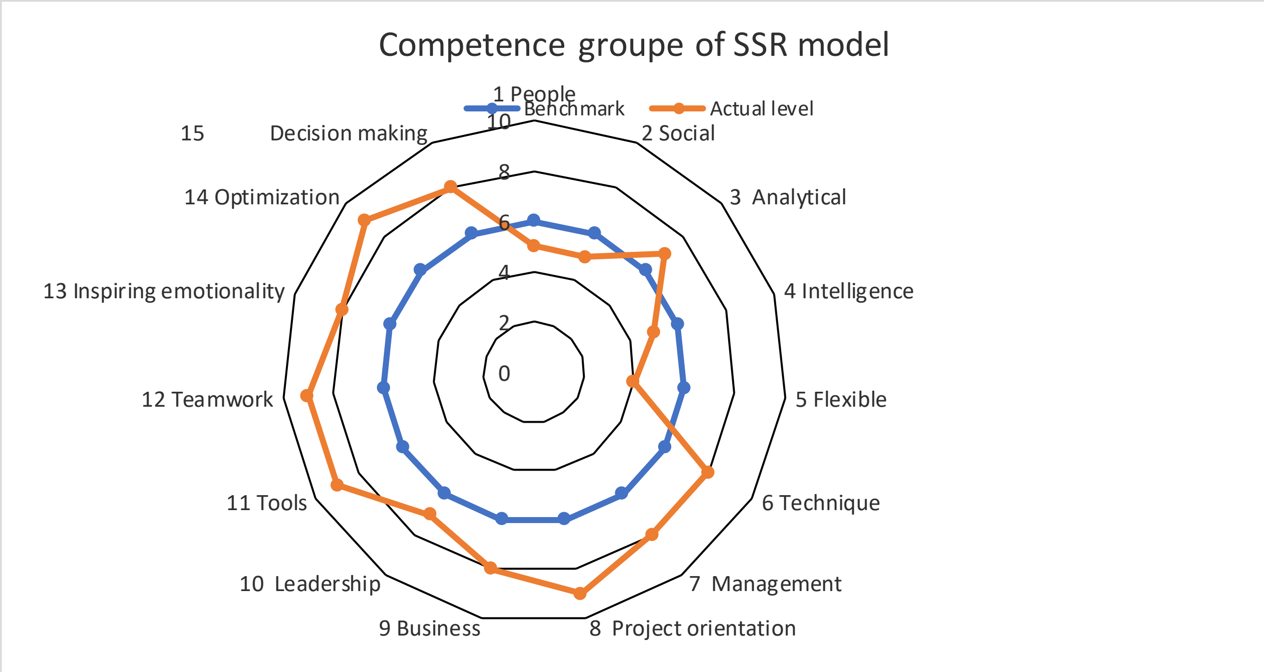

Figure 4. Spider diagram of Inspiring Emotion key competencies by framework Strategic Sustainable Renovation (SSR)

After analyzing the results of the assessments, the team was offered creative exercises to develop the competencies of the People group.

The re-evaluation showed the effectiveness of the exercises. A follow-up evaluation two weeks after the corrective actions is shown in Table 2 and Figure 5.

Table 2. Model of key competencies for Inspiring Emotion for Strategic Sustainable Renovation (SSR) after corrective actions

№	Group/competence	Benchmark level of inspiring emotion to project success (from 1 to 10)	The level of influence on inspiring emotion (from 1 to 10)
1	**People**	6	7
2	Social	6	8
3	Analytical	6	7
4	Intelligence	6	7
5	Flexible	6	9
6	**Technique**	6	8
7	Management	6	8
8	Project orientation	6	9
9	Business	6	8
10	Leadership	6	7
11	**Tools**	6	9
12	Teamwork	6	9
13	Inspiring emotionality	6	8
14	Optimization	6	9
15	Decision making	6	8

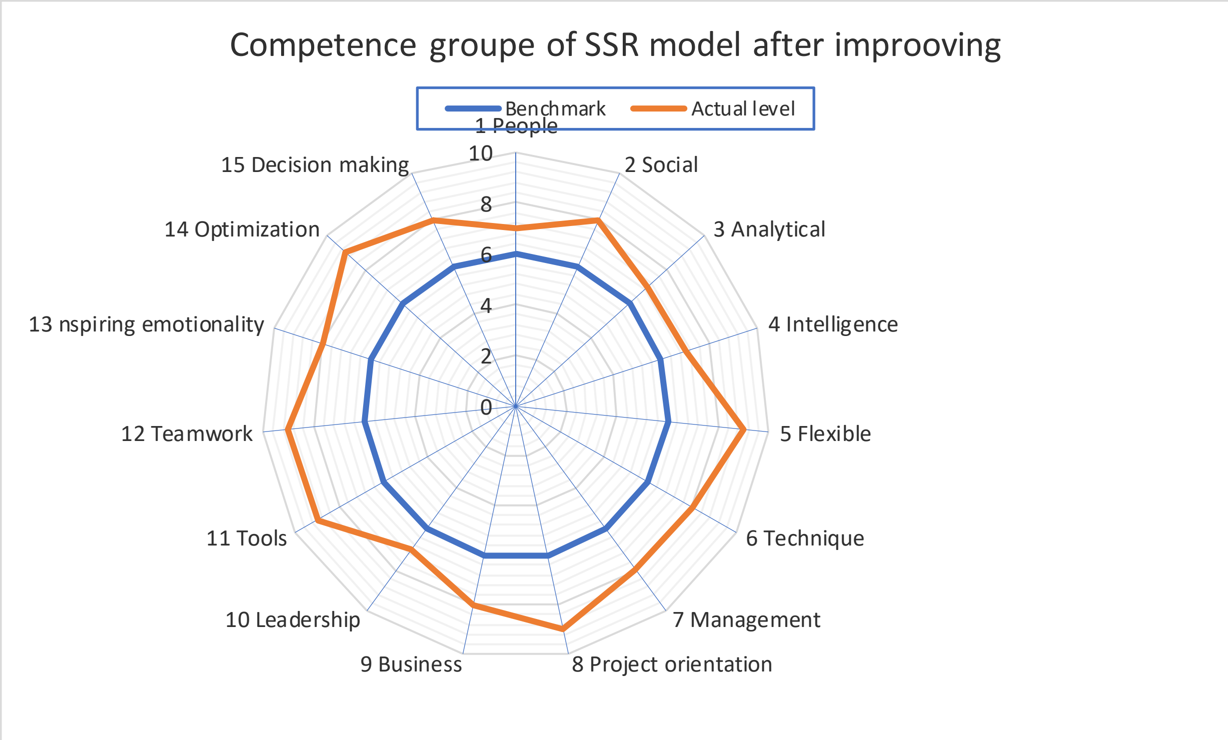

Figure 5. Spider diagram of Inspiring Emotion key competencies by framework Strategic Sustainable Renovation (SSR) after corrective actions

A comparative analysis of the proposed approaches to determining the impact on the strategic stability of the system based on the competence model shows the greatest effectiveness of the holistic approach. This approach forms the broadest view of the manager on development projects, a very high level of creativity and intelligence in decisions. This approach is applied with the IPMA Delta and OCB model and ensures the maximization of inspirational emotions in the process of implementing projects and programs.

Qualitative assessments of the impact of competencies on the formation of inspiring emotion were determined by a group of ten experts in the project for the reconstruction of a destroyed object in the city of Bucha, Kyiv region from the educational program "Project Management” at Kyiv National University of Construction and Architecture.

4. Conclusions

The groups of competencies that form inspiring intuition within the model are defined - as the Framework for Strategic Sustainable Renovation.

The proposed qualitative model for assessing the impact of inspiring intuition on the processes of preparation and decision-making in IT project management allows us to identify the main creative techniques and competencies that determine the success of IT projects based on inspiring intuition. Thus, in the given example the holistic creative technique had the greatest influence on the strategic success of the projects.

The study of each model allowed us to identify groups of competencies and their impact on the formation of inspiring intuition for the implementation of innovative projects and programs.

Further research is needed to determine the impact of inspiring emotion on the success of renovative projects

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Game Theory Application in Public Procurement Procedures in Construction

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Abstract:

This research paper aims to bring closer the concepts of game theory and public procurement and to point out their connection and all the possibilities that the application of game theory opens in the field of public procurement in the construction industry. The idea behind the research was that game theory is used in public procurement processes, but that the players themselves, or bidders, may not be aware of this fact. In addition, the paper points out the existing application and some new possibilities. The process of creating this paper was based on the study of the already existing literature on game theory followed by a study of Croatia's Public Procurement legislation. To gain further understanding of the two unrelated concepts and their potential interrelations, a survey was conducted in the form of an informative interview with two construction companies. Through these conversations, real possibilities of applying game theory were noticed, as well as the desire of companies to apply the game theory principles, while also realizing shortcomings that could occur. Finally, the paper presents a mathematical model which can be used as a decision support tool in the public tendering process, which was tested in two bidding processes. The application of game theory is not recommended as the only approach to public procurement tenders, but combined with experience, calculations, and other expert knowledge, it can certainly contribute to a better understanding of competition in public procurement bidding processes and increase the chances of success.

Keywords: *game theory; public procurement; bidders; bidding process; competition; mathematical model; decision support tool*

1. Introduction

The field of construction, especially management in construction companies, meets with many problematic situations in which the decision that will bring the greatest benefit needs to be made. Problems such as what to build, how much to invest, and how to perform certain works are very common, but the basic problem of this paper is the problem of creating a bid for public procurement tenders. For the most part, it comes down to the question of how low a price we can offer to be ahead of the competition but still manage to keep up some profit. Such decisions are mainly the result of the experience and intuition of the company's management which makes the final decision on the amount of the bid for a particular tender.

Intuition-based decision-making often comes with problems because it is a very unreliable way of choosing strategies and making important decisions, and one wrong move can lead to business failure. That's why more attention is focused on mathematical models and tools that can solve such situations by considering all factors of influence and as a result, providing the best strategy to be guided with. That is also the motivation of this paper; pointing out the possibilities of using mathematical models instead of traditional predictions based only on experience and intuition. Of course, such models are not perfect either, and they have many disadvantages to consider when using, but can certainly be of significant help to the user. One of the most important mathematical methods applicable in the process of creating a bid is game theory, which will be explained in more detail in the second chapter. The bidding and competition process usually occurs in public procurement processes. Public or sectoral clients, for works that exceed the monetary values determined by the Public procurement act, must provide public competition for such works, i.e., in the public procurement procedure, which is the main topic of the third chapter of this work. Such tenders are attractive to a large number of bidders because they usually come with longer business contracts or opportunities to make a significant profit. But a large number of bidders also means significant competition, i.e., low chances of winning a contract if the offer is not created thoughtfully.

Bidding is a conflict situation between several bidders, each bidder wants to secure a job for themselves which means taking away a job from others (King and Mercer, 1987). This is a perfect example of a zero-sum game, one player wins and gets all the profit, while others remain at nothing. Using the principles of game theory, the player can analyze and assume the moves of his rivals and accordingly find his dominant strategy to achieve the desired result and maximize their profits (Kreps, 1990). Of course, without knowing the exact information about competitors, game theory cannot guarantee success, but by planning and recognizing their dominant strategy, the bidder can greatly increase their chances of winning on a tender. The basic idea of this paper is to find a link between game theory and public procurement processes, as well as point out the possibilities of applying these methods in construction companies and the fourth chapter is dedicated to this. The fact is that in many companies such methods are used informally, i.e., without knowing that these are game theory methods, but they are nevertheless used daily in creating offers. For that reason, this paper will try to bring closer the possibilities and advantages of using the game theory model, but also mathematical models in general, because their application can greatly facilitate the work of management and increase the chances for success in public procurement tenders.

2. Methodology

For purpose of writing this paper, detailed literature research was conducted on relevant scientific indexing databases. Results of the search consisted of scientific papers on game theory and Public Procurement Act. After that, research data was analyzed and a connection between game theory and public procurement was established. Additionally, public procurement bidding processes were studied to identify qualification requirements and to be able to begin the creation of the model.

To gain insight into practical application, a two interviews with professionals in the bidding process were conducted. One of the experts was employed in a contractor company, while the other was employed in a design and supervision company.

The interviews were semi-structured, consisted of 16 questions with questions, with regards to their experiences in the public procurement, their tendering processes, and their views on using a mathematical model based on game theory to quantify bids.

After the interviews and their input, as a final result, a theoretical mathematical model was created for purpose of applying game theory principles in process of public procurement.

The model was tested to see what the results would be if it were applied on two cases. First one was for construction works on a state road DC501 Oštrovica - Meja, length 7,2 km, and the second one was for design services on the project of improving the infrastructure of Sands of Đurđevac tourist complex.

3. Game Theory

3.1. Decision Theories

Decision-making has always existed. Throughout history, people have made decisions without even realizing it. Choosing a decision involves a set of at least two options from which to choose one to achieve the desired goal (Keeney *et al.*, 1993). In the world of managers, most of the time is spent on decision-making. The way a manager makes decisions classifies him into one of two groups: the experiential decision making (using only their experience and knowledge to decide) and scientific decision making (solving decision-making problems using mathematical laws, with various applications and software) (Roljić *et al*., 2013). Experiential decision-making often proves to be the wrong choice, managers often make the wrong decision based on their feelings and endanger their project, but also possibly the entire company. Decision theory is a process that provides help for using scientific methods and systematic research, to the decision-maker, in choosing the optimal strategy for achieving the desired goal (Körding KP and Wolpert DM, 2006) Therefore, a decision is the result of the analysis and evaluation of alternative solutions to achieve the goal. The process of conducting analysis and choosing one of at least two alternatives is called a decision-making process. The theory itself studies the situations in which the decision is made, regardless of the situation in which the individual finds himself, regardless of the risks and unknowns that may affect the decision, but also the final result. In the problem of choosing between two or more alternatives, there are goals to be achieved by that decision, the criteria by which the achievement of those objectives is measured, the weight of those criteria which reflect their importance, and alternative solutions to problems (Roljić *et al*., 2013).

3.2. Mathematical Programming

Mathematical programming is a conceptual approach but also at the same time a set of techniques and algorithms for defining (modeling) and solving a special class of tasks. Mathematical programming is solving optimization problems that are presented in mathematical form: by a goal function or a criteria function to find the extreme (max or min) within a set of functions that limit the domain in which it is a specific goal function. The objective function together with the limiting functions makes up a mathematical program, and "programming" is the process of finding such values of variables in a task while at the same time the limitations are met, but also the goal achieved. Obtained values at the end of solving the mathematical programs are optimal, and all the steps from setting a task to its solution are called mathematical programming (Roljić *et al*., 2013). There are several divisions within mathematical programming. Considering the number of goal functions is divided into single-criteria programming and multi-criteria programming. Observing the form of the goal and constraint function, it is divided into linear (linear tasks only), integer (tasks with integer variables), quadratic (tasks with quadratic goal functions), and nonlinear programming (tasks in which there is some nonlinearity either in the function of the goal or in the limitations of the functions) (Vajda S, 2009). A special part of mathematical programming is dynamic programming that solves problems of optimal sequential decision making (Roljić *et al*., 2013).

Multi-criteria optimization tasks in cases where important decisions such as financial decisions are considered and are characterized by a relatively large number of criteria, not two or three but ten or even more. The more criteria, the harder it is to get results. For a more efficient analysis of the decision and finding a suitable solution, the criteria are grouped. The following groups of criteria are common: economic, technical, technological, social, and environmental (Roljić *et al*., 2013). Deciding methods for problems with multiple criteria is a field that is still evolving and aims to provide some tools and methods to decision-makers that would allow them to make even more progress in solving complex decision-making problems where usually a few contradictory criteria must be considered. In practice, there is no ideal or perfect solution to the problem programming with multiple criteria, i.e., a solution that is best at the same time for all of the criteria, instead it deals with compromise solutions that meet as many criteria as possible (Ehrgott M, 2005). An issue of multi-criteria decision-making is a situation in which after a set of activities (decisions, variants) are defined, the decision-maker:

• defines a subset of the set of variants that is best concerning the set of criteria (selection problem),

• divides a set of variants into subsets according to certain norms (sorting problem)

• ranks a set of variants from best to worst (ranking problem) (Roljić *et al*., 2013).

3.3. Introduction to Game Theory

Game theory is a branch of applied mathematics that deals with the study of conflict and cooperation between intelligent and rational decision-makers. It provides general mathematical techniques for analyzing conflict situations in which two or more participants of opposing interests need to decide (Petrosyan LA and Zenkevich NA, 2016). Turning real, conflict situations into mathematical models can greatly facilitate the prediction of possible outcomes and choosing the best strategy. The name "game theory" came about because of typical examples. Conflict situations are represented by social games such as chess, card games, and even sports match. Most of the terms used in game theory are very similar to those in social games but theory games have a much wider application outside the realm of social games. Concepts and models of game theory are becoming more and more used in economics, military strategy, mathematics, politics, and even construction. Except for the name "theory games", in scientific circles, there are also the names "conflict analysis" and "interactive theory decision-making" which more precisely indicate the purpose of using this theory (Barković Bojanić I and Ereš M, 2013).

Game theory models are very abstract depictions of a large number of real-life situations. Their abstractness allows them to study a wide range of phenomena. For example, Nash's theory of balance was used to study oligopolistic and political competition. Repetitive game theory has been used to illuminate social phenomena such as threats and promises. The core theory reveals an understanding in which the outcome of trading in a price system is stable in an economy that contains a multitude of factors (Osborne MJ and Rubenstein A, 2011).

The basic concepts in game theory are game, players, strategy, and the outcome of the game. A game is an activity in which two or more players of different interests and conflicting goals participate, but the game is also a set of rules that players must adhere to (Barković Bojanić I and Ereš M, 2013). The strategy game model is interactive decision-making in which each decision-maker chooses their action plan, and those decisions are made at the same time. When used to describe the actions of players in a strategy game, "simultaneously“ does not necessarily mean that these actions were taken at the same time. To model the situation as a strategy game, it is only important that the players make decisions independently, no player is informed of the selection of any other player before making his own decision (Osborne MJ and Rubenstein A, 2011).

For a game to exist, at least two players must participate. Each of the players wants to develop the most favorable strategy for themselves by which they will gain an advantage over other players and optimize their profit, which is the main goal of game theory (Petrosyan LA and Zenkevich NA, 2016). The models we study assume that each player is rational, that they are aware of their alternatives, form assumptions about all the unknowns, have clear preferences, and make their planned decisions after some optimization process. In models that we study, individuals often have to make decisions under conditions of uncertainty. Players can be:

- insecure in objective environmental parameters
- imperfectly informed about events that occur in the game
- insecure about the actions of other non-deterministic players
- uncertain in the reasoning of other players (Osborne MJ and Rubenstein A, 2011).

When choosing a strategy, the player is faced with a possible choice: on the one hand, the player wants their strategy to serve as well as possible for achieving their goal while on the other hand, they want the simplest possible strategy, and choosing one of the two options excludes the other. There are many reasons why players appreciate the simplicity of the strategy – the more complex the plan of action is more likely it is to fail, it is harder to learn, and it can take a longer time for implementation (Osborne MJ and Rubenstein A, 2011).

The game can be structured in two ways, i.e., there are two possible types of outcomes of the game - variable or a constant sum. In games with a constant sum, players have strictly conflicting interests, and the profit of one player represents the defeat of the other while in games with variable sum players are at the same time in conflict, but also agree. Games with a sum are also called strictly competitive games (Petrosyan LA and Zenkevich NA, 2016). We say that the player maximizes their profit if they choose the action that is best for them under the assumption no matter what they choose, other players will choose an action to hurt them or their profit as much as possible. In a strictly competitive game, Nash's balance can be seen, if the action of each player maximizes their and minimizes the outcome of the opponent (Osborne MJ and Rubenstein A, 2011). Nash’s balance is often associated with the term dominant strategy even though Nash’s balance doesn’t have to necessarily include dominant strategy. A dominant strategy guarantees the best outcome for a player using it, no matter how his opponent plays. It can be strictly dominant, that is, choosing such a strategy will always achieve a better result in the game (higher payout) than choosing any other strategy. In reality, more often is a weak dominant strategy that in any case ensures a positive outcome of the game, but not necessarily the best possible outcome. (Osborne MJ and Rubenstein A, 2011).

3.4. Disadvantages of Game Theory

Game theory is based on the rationality of decisions, but every decision can be rationalized for the sake of benefit, whether good or bad. It is difficult to define, constrain, isolate, and determine variables for all factors affecting the final result of the game, there can always be one unpredictable factor. When deciding, it is assumed that each player will decide to maximize their profits, but every decision is influenced by several dynamic factors from the environment. The fact is that the model in game theory is so abstract that it allows application in a wide range of situations, but this abstraction is also a disadvantage because the implications of the model cannot depend on the specificity of a situation. Very few conclusions can be drawn about the outcome of the game at this level of abstraction; to get interesting results, the game would have to be much more detailed and precisely defined (Barković Bojanić I and Ereš M, 2013).

Game theory is certainly not suitable for analysis in all scenarios. The difficulty in using game theory is that decisions and outcomes cannot be measured empirically. The elementary assumption of game theory is that players are completely rational and that all the decisions they make are made solely to maximize their profits or income, which in real-life situations most commonly is not so (Barković Bojanić I and Ereš M, 2013). When we talk about games in real life, we often do focus on the asymmetry between individuals in their abilities. For example, some players may have a clearer perception of the situation or a greater ability to analyze it. As an example, take a game of chess. In the real game of chess, players can differ in their knowledge of the allowed moves and their analytical skills. But when chess is modeled using a current game theory it is assumed that the player's knowledge of the rules of the game is perfect and their ability to analyze the game is ideal. Modeling the asymmetry in abilities and the perception of the situation by different players is a challenge for future research (Osborne MJ and Rubenstein A, 2011).

3.5. Application Of Game Theory in Construction

During the management of construction projects, conflict situations often arise between the client, the contractor, subcontractors, etc. There are various reasons like prices, payments, delays, disagreements over the method of performance, and many others (Gardiner PD and Simmons JEL, 1992). A solution where all parties are at a profit would be ideal, but often the opposite happens through wrong decisions. Therefore, the goal is to find a way or method to deal with conflict situations to achieve a positive outcome and make the whole project progress. Game theory allows just that, through its study of human behavior, allows the user to come up with the most favorable solution for the project in a non-cooperative situation. The most common problem with cases like this is that all parties prefer their profit rather than the total joint profit of the project and therefore optimization methods cannot be applied to conflicts in construction projects. Another possibility of applying game theory is when choosing a location for a project. The player starts with several possible locations, considers all the possibilities, advantages, and disadvantages, and as in each the game is trying to come up with an optimal solution, that is, a solution that will ultimately bring them the greatest profit (Peldschus *et al*, 2010). The procurement process does not need to be exclusively a zero-sum game. Pham and Phan (2021) for example, have researched the potentials of compensating the most highly ranked unsuccessful bidders to motivate contractors to put in extra effort or input in bid preparation. In any case, whether there is zero or some benefit to unsuccessful bidders, tendering process still predominantly remains highly competitive and with potential to use mathematical models in determining optimal bid price.

4. Public Procurement in Construction

Public procurement is a very important segment of any economy; a regulated public procurement system manages the spending of taxpayers' money to ensure the best value for that money.

The main goal of each of the contracting authorities in the public procurement procedure is the implementation of the legal procedure which ensures efficient public procurement and economical spending of public funds. They aim to make a contract with the bidder who has proven through the public procurement procedure that he can meet all the requirements, criteria, and needs of the client for the delivery of goods, performance of work/services, and possesses all the resources necessary to fulfill that obligation. A special type of public procurement is mixed procurement used in the procurement of two or more different types - one part of goods, one part of services, and similar (HAMAG BICRO, 2017).

The public procurement procedure uses an electronic advertisement to announce tenders and conduct their procedure. Advertisement is obligatory for all users of public procurement and all data entered in the advertisement must be true. The advantages of the electronic advertisement are (PPL, Chapter 6, Article 68):

- allows contracting authorities to compile, edit, submit for publication, or withdraw from publication public procurement notices on standard forms and make them available, free of charge no later than 18:00 on the day designated as the day of sending a post for publication
- submits standard forms to the Publications Office of the European Union for publication in the Official Journal list of the European Union
- publishes public procurement notices on standard forms, for a fee, together with accompanying procurement documentation on the website
- provides all interested parties with unlimited and immediate access, search, review, and download published public procurement notices and related documentation on procurement, free of charge
- enables users to draw up and send requests to participate, tenders, plans, and projects, free of charge
- keep records of registered entities
- manages the entire database of published public procurement notices and publishes them publicly as machine-readable data in the current month for the previous month
- provides access to the database to the central state administration body responsible for public procurement policy, the State Commission for the Control of Public Procurement Procedures, and the Attorney's Office of the Republic of Croatia
- Electronic transmission and publication of public procurement notices, procurement documents, electronic transmission and delivery of bids, participation requests, qualification requests, plans, and projects are implemented through the EOJN RH.

- Clients may communicate and exchange data electronically.

4.1. Law on Public Procurement

The Public Procurement Act is the basic law of the public procurement system. This law regulates public procurement procedures in which contracting authorities and tenderers enter into contracts for public works, supplies, or services, and the competencies of the body responsible for the public procurement system and legal protection in connection with public procurement procedures. Public procurement in the sense of this Law is procurement through a contract on public procurement of goods, works, or services procured by one or more contractors selected by those contracting authorities (LPP, Chapter 1, Article 1).

The basic principles of the Public Procurement Act are (LPP, Chapter 1, Article 4):

- In the application of this Act concerning all economic entities, the contracting authority is obliged to respect the principle of freedom of movement of goods, the principle of freedom of establishment and the principle of freedom to provide services, and the resulting principles, such as the principle of competition, the principle of equal treatment, the principle of non-discrimination, the principle of mutual recognition, the principle of proportionality and the principle of transparency.
- Public procurement may not be designed to avoid the application of this Act or avoid the application of low or high-value public procurement rules or unjustifiably favor or disadvantage certain economic operators.
- The contracting authority is obliged to apply the provisions of this Act in a manner that enables effective public procurement and economical and purposeful spending of public funds.
- The investor is obliged to adhere to the applicable obligations in the field of environmental, social, and labor law, including collective agreements, and in particular the obligation to pay the agreed salary, or the provisions of international environmental, social, and labor law listed in Annex XI. of this Act during the execution of the public procurement contract.

4.2. Simple Procurement

Procurement of goods, services, and works of value below the thresholds mentioned earlier is called simple procurement and is not covered by the Public Procurement Act. The rules, conditions, and procedures of simple procurement are determined by a general act, considering the principles of public procurement and the possibility of applying electronic means of communication. The general act must be published on the website of the public or sectoral client (LPP, Article 15).

For the procurement of works, goods, and services of estimated value equal to or greater than HRK 20,000.00, and less or equal to HRK 200,000.00 for goods and/or services; or less than or equal to HRK 500,000.00 for works, the contracting authority will request tenders from three bidders. Exceptionally, due to urgency, technical or other justified reasons, and if there are no 3 subjects that can deliver goods, provide services, or perform works on the market at the time of initiating the procedure, the Client may request the submission of bids from a smaller number of bidders. The deadline for the submission of tenders may not be less than five days, except in exceptional cases of urgency provided that a shorter deadline is enough to submit a bid. The criteria for selecting a bid are the lowest price or the economically most favorable bid.

4.3. Division of Public Procurement by Thresholds

In addition to simple procurement, we also distinguish between high-value procurement and low-value procurement. High-value public procurement is determined by a European directive, i.e., the so-called European threshold. Low-value procurement is the acquisition of everything between simple procurement and procurement of high value. In Tables 1 and 2, the values of the lower and upper thresholds for each of the three types of procurement are shown separately for the procurement of goods or services and separately for the procurement of works. The value that indicates the upper threshold of low-value public procurement, i.e., the lower threshold of high-value public procurement is called the European threshold and is determined by directives of the European Union.

Table 1. European threshold for public procurement of goods and services

Procurement of goods or services	Lower threshold	Upper threshold
Simple procurement	20.000,00 HRK	200.000,00 HRK
Low-value procurement	200.000,00 HRK	5.574.150,00 HRK
High-value procurement	5.574.150,00 HRK	x

Table 2. European threshold for public procurement of works

Procurement of works	Lower threshold	Upper threshold
Simple procurement	20.000,00 HRK	500.000,00 HRK
Low-value procurement	500.000,00 HRK	39.762.270,00 HRK
High-value procurement	39.762.270,00 HRK	x

5. Application of Game Theory in Public Procurement Procedures

5.1. The Basic Idea of Game Theory Within Public Procurement

It may not be easy to see the connection between two seemingly unrelated concepts such as game theory and public procurement, but the connection does exist. Public procurement through the concepts of game theory can most easily be described as a conflict situation in which multiple players are competing with each other to achieve the goal, that is, winning the contract. Players in the "game" of public procurement are all bidders who appear in competition, they observe their competitors, try to anticipate their moves and decisions, their bids, and compare their references and knowledge, workers, and machines with what competitors have. A detailed analysis of the bidder is the first step of creating the offer, which must provide profit, but on the other hand, be a more competitive option than all other offers to secure a job. The bidder can make his strategy, i.e., bid, the optimal choice for the client by influencing the price of their offer, by lowering or raising the price concerning references, workers, the technology they possess compared to their opponents, which the contracting authority has indicated as necessary for job execution. If the bidder meets the required qualification requirements by the investor to a lesser extent, the price will have to be lowered low enough to make it more acceptable to the contracting authority nonetheless, and if the bidder better meets the required qualification requirements than the competition, then he can accordingly go higher at a price that justifies its quality. The goal or reward of the game is the contract for which the bidders are competing, i.e., the monetary value, the profit which the contract brings for the bidder. Considering that this is the core business of the bidder, something of which they maintain their business and pay the workers, this goal is certainly very important to achieve even with minimum profit, because even the smallest profit will ensure a positive return. The process itself is marked by conflict between bidders, but also by the conflict between bidders and investors. The situation between the bidders is clear, they compete to make a profit. Nevertheless, there is also a conflict between the investor and the bidder. The bidder, of course, wants the highest possible price for their service, while investors want to lower the price as much as possible, but with the same quality assurance. To even to be considered for the selection process the bidder must first fulfil the financial and technical qualification requirements proposed by the tender documentation.

5.1.1. Financial qualification requirements

Financial qualification requirements assess the financial standing of bidders to ensure that they are financially stable enough to carry out the contract. To assess this for construction works, some of the often-asked qualification requirements are:

- Statement on the total annual turnover of the economic entity in the last 3 financial years. The average turnover must be greater than or equal to the estimated value of the procurement.
- Proof of the solvency of the bidder
- The sum of values (excluding VAT) of work performed in the year in which the procedure began must be at least equal to the amount of the estimated value of the procurement.
- Liability risk insurance
- Reliance on the ability of other entities
- 2 similar performed contracts whose sum of values must correspond to the estimated value of the procurement
- The bidder must prove in the public procurement procedure that its account has not been blocked for more than thirty days in the last six months.
- Total revenue in the previous year greater than or equal to the value of the procurement

For engineering services, such as supervision, design, or project management, some of the financial qualification requirements may be:

- The sum of values (excluding VAT) of a maximum of three services provided must be at least half of estimated procurement values of which at least one service provided relates to supervision of the facility specified in the tender
- Turnover in the previous year greater than or equal to the value of the bid
- Insurance policy

5.1.2. Technical qualification requirements

Technical qualification requirements are used to assess the bidder's capability. Bidders are asked to provide relevant examples of previous work to demonstrate that they have sufficient experience to deliver the contract, which for construction works can be:

- Minimum required professionals and experience required to perform the work
- At least one confirmation from the other contracting party on the proper execution and outcome of the same or similar works subject to the procurement of a value at least equal to the estimated value of this procurement
- List of works performed in the year in which the public procurement procedure began and during five years that precede that year
- Statement on the equipment and machinery available to the contractor to perform the contract
- Statement of tools, plants, or technical equipment
- Certificate of proper execution of 2 similar contracts

For engineering services, such as supervision, design, or project management, some of the technical qualification requirements may be:

- Minimum required professionals and experience required to provide services
- Accredited laboratory per the standard HRN EN ISO / IEC 17025
- At least one confirmation from the other contracting party on the proper execution and outcome of the same or similar works subject to procurement in the last three years
- Proof that in the year in which the public procurement procedure was initiated and during 3 years before that year, duly provided services that are the same or similar to the subject of the procurement

5.2. Selection Criteria

The application of game theory in public procurement is most obvious in the economic selection criteria for the most acceptable offers. As said, several qualification requirements can affect the final selection; price is an important factor and most often the only one that companies can adjust to increase their chances in the tender, but several other criteria are considered when evaluating the bid. The investor selects up to two non-financial criteria that are important to them for the selection, in addition to the corresponding percentage assigned to each of the criteria. Percentages, in the greater part of the tenders, range between 10 and

20%, but sometimes reach higher values. Some of the criteria often found in public procurement tenders are:

- Warranty period
- Professional / specific experience
- Additional duration of the warranty period for the delivered price
- Qualitative evaluation of the offer
- Guaranteed annual operating costs

In some tenders, the price can be the most important selection criteria which usually results in the contract being awarded to the one bidder with the lowest total price. More often, investors try to choose the bidder that offered an economically most favorable offer, which doesn't need to be one with the lowest price. It is the offer that proves the best when considering several criteria including but not limited to price, quality, delivery, technical merit, compatibility, functionality, and overall cost-effectiveness.

If the company applying for the tender recognizes its advantage in any of the certain qualification requirements compared to the competition, such a company knows how much it can raise the price, because it has secured points for non-financial criteria. Also, a company that knows it may not meet some of the criteria, may not have enough experience or required years of work in a particular area, for that reason would lower its price, and maybe even up to the lowest level of profit, i.e., to a business with a positive zero, to still ensure an advantage compared to the more experienced competition and to compensate for the lack of non-financial criteria.

5.3. Interviews

To better understand the topic of this paper and to get information about the real situation in the field of public procurement in the Republic of Croatia and the possibilities of applying game theory, two interviews were conducted. Interviews were conducted with two different companies, one that deals with providing engineering activities (design, professional supervision, project management) and the other which provides activities related to the execution of construction works. The questions themselves were formed to gain insight into the way of doing business, i.e., how important public procurement is to them in their business. Also, part of the questions is based on the formation of offers, because this process is different from company to company, everyone has their principles, their experiential assessments, and their methods. And finally, part of the questions targeted the field of mathematical modeling, i.e., game theory. The goal was to figure out if the companies were instructed in the use of mathematical models, if they use something like that and if they see the advantages of such ways to create an offer. In addition, the goal was to better understand the situation in practice, that is, what can be expected, what is applicable and what is not, and whether there are any conditions for the application of game theory itself.

5.4. Mathematical Model for Creating an Offer

Through interviews with respondents, it was found that there is a desire to use a mathematical model that would include selection criteria for the company as well as competitors and facilitate the determination of the final price offers. It could also be concluded that the respondents are already partially using the advantages of game theory through their everyday work but without a formal model. Including all the information gathered through informative interviews (selection criteria and their shares, recognition of references and competencies, final price corrections, etc.), a mathematical model was developed. This model will try to show the real advantages of using game theory in the public procurement process.

For this paper, a mathematical model has been developed as a basis from which to proceed to more detailed development and use of modeling in public procurement processes. The model was conceived as (1):

$$C_P = C_K \pm \left(\alpha_{K1} \cdot \frac{R_{P1}}{R_{K1}} + \cdots + \alpha_{Kn} \cdot \frac{R_{Pn}}{R_{Kn}} \right) \cdot \alpha_C \cdot C_K \cdot (1 - r) \tag{1}$$

$$\sum_{i=1}^{n} \alpha_{Ki} + \alpha_c = 1$$

$$r \in [0,1]$$

In order to clarify the model, the following is an explanation of the model's elements:

- C_P - estimated bid price, i.e., price proposal in which the selection criteria and risks are included. With this price, the chance of winning the tender should increase significantly.
- α_{k1} - α_{kn} – the percentage of certain selection criteria, indicates the percentage of points on the tender (0-100%) that belongs to each criterion. For example, in a tender, 30% of points are given for the criterion of expertise, so in this case $\alpha_k = 0.3$. This is a completely known factor because it is publicly announced in the tender.
- α_c - percentage share of price criteria, indicates the percentage of points in the tender (0-100%) belonging to the price criterion. For example, in a tender, 50% of the points are awarded for the price criterion, so in this case $\alpha_c = 0.5$. This is a completely known factor because it is publicly announced in the tender.
- R_{P1} - R_{Pn} - points that a company using this model can get for certain criteria of choice. Completely known element because the company knows its competencies.
- R_{K1} - R_{Kn} - points that a company using this model assumes for the competitive company for certain selection criteria. It is not a completely known element because the company does not know all the competencies of competitors, but a lot of things can be assumed or concluded based on past experiences.
- C_K - the bid price that the company using this model assumes for its competitor. The data is based solely on experience because there is no certain way to know how much the competition intends to offer for a particular tender but through years of experience and through monitoring the competition the company can get some insight into how competitors make their offers.
- r - risk factor. This factor includes the risks of assumptions for information on selection criteria and prices offered by the competition. As the risk factor consists of two different elements, it could be broken down into these two parts: r_k for selection criteria and r_c for the price offered by the competition. If the criteria were separated,

then instead of (1 - r) in the model we would have (1 - r_k) · (1 - r_c). The purpose of using risk factors is to increase your safety because if there is no complete certainty in a particular selection criterion or price the competitor could offer, it is better to add a certain risk percentage to lower the offer but provide a greater chance of winning the contract. As stated in the model, the risk factor ranges between 0 and 1, including both limit values. The risk factor will be 0 in the case when the company is completely sure in their assumptions, that is, then these are not assumptions but verified information about the competition. Such a situation would allow for a precise bid price that would allow for a secured significant profit because the company would offer the maximum price, and they would still have the highest number of points in the competition. Such a case is difficult to expect in practice. A case in which the risk factor would be 1, would indicate a situation where there is no information about the competition, the model itself would give a solution of C_P = 0, which is by no means a useful piece of information. If the situation would be such that bidding would be completely without information about competitors it makes no sense to use such a model at all because it is a situation in which a mathematical model cannot help with the decision, the decision should be made in some other way, or it would be better to withdraw from the competition.

A model like this enables an estimate of the price at which to bid, or at least can be used as some kind of a guideline that would aid in making the final decision. Also, the model could be used as well in post-tender situations where the prices offered would be known, it could be used for estimates of competition points on certain selection criteria that may not have been known before tender. Although this is just an initial idea that can certainly be developed more to provide the greatest possible benefit to users.

5.5. Testing the potential of application

The developed model was tested on two cases. First one was for construction works on a state road DC501 Oštrovica - Meja, length 7,2 km, and the second one was for design services on the project of improving the infrastructure of Sands of Đurđevac tourist complex. The examples were chosen from the real public procurement bidding processes, in which the interviewees have participated. It is important to note that the model was not used during the bidding process, but after the fact, once all bids were opened to see how the model could have been used to raise the bid price in order maximise profits or to reduce the bid price in order to secure the bid.

For the construction works tender, all but one of the total of five bidders had identical points in technical qualification requirements. This would mean that between four bidders, the price of the bid was the only differentiating factor and that the fifth bidder would need to lower the bid price substantially to cover the difference in points. Lowest bid out of the four bidders was 38.000.000,00 HRK and the model was used to determine that the fifth bidder would need to submit a bid of 36.803.000,00 HRK to win the contract. It is of course easy to determine this number after all bids are open, the most difficult part is to predict the financial and technical competences of the competition, but the example shows how the model can be used.

The second example follows a similar calculation, but from a point of a winning bidder. Based on the data after the bids were opened, it was determined that the bidder could have offered 230.076,00 instead of 198.000,00 HRK and still be the winning bidder. This example also shows the potentials of using the model in deterministic circumstances, but however, due to the ability to guess with sufficient accuracy the competences of competitors and to factor in risk, the model could prove useful at least as an additional tool in the bidding process.

6. Conclusion

This paper covers two very well-known concepts in the field of construction management. First, game theory is very well known in theory, but not so much in the practical application. It started with the idea of game theory as one of the examples of mathematical modeling that finds its application in the process of submitting tenders without the tenderers themselves being even aware of it. Prediction, assumptions, competition analysis, and competition alone are very characteristics of the theory games, but the question is whether the game theory has been used to its full potential. With initial assumptions about the parts of public procurement that their characteristics correspond to one of the games from the game theory, additional research was conducted on the frequent qualification requirements of application and selection criteria. Dozens of public procurement tenders were studied, and selection criteria were selected, which appeared in the largest number of competitions. These criteria are the reason for the application of game theory. In them, players recognize the advantages and disadvantages over competitors. By analyzing and gathering information through numerous competitions, the company can have a clear picture of competencies, references, staff, work technology, and several other factors of its competitors. By comparing themselves to the competition to adjust their offer to make it optimal for the client, and the company benefits by achieving maximum profit.

In conducting research for this paper, there were some limitations such as a lack of literature on the application of game theory in public procurement, and a very small number of respondents in practice; it would be necessary to increase the sample significantly for a better understanding of the practical application. But even with these limitations, it can be concluded that the set goal was achieved, the connection of game theory with public procurement is shown, the possibilities of application are pointed out, but also an example of a mathematical model was made that could be applied in practice. This topic could certainly be developed further since a lot remains unknown. One could continue to develop the mathematical model itself and even the software that would consider all the criteria and such software could be tried in practice to better identify advantages and potential problems. Game theory has its place in public procurement, but of course, needs to be further researched and developed to ultimately offer significant advantages over traditional methods.

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Construction Health and Safety Practices on a Roads Agency's Projects

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Abstract:

The South African construction industry contributes a disproportionate number of fatalities and injuries relative to other industrial sectors, and there is a high level of non-compliance with health and safety (H&S) legislation and regulations in the industry. The current study sought to determine the construction H&S practices on a roads agency's projects. The quantitative method was adopted for the study, which entailed a self-administered questionnaire distributed to construction H&S agents, civil engineers, H&S consultants, design managers, construction project managers, depot managers, and resident engineers involved with the agency's projects. The salient findings include: respondents generally consider H&S during the six stages of projects and on eighteen occasions, and undertake nine H&S-related interventions on the roads agency's projects; fourteen multi-stakeholder interventions impact on H&S to a major as opposed to a minor extent; twelve interventions positively affect construction H&S to a major as opposed to a minor extent, and respondents rated themselves above average relative to twelve H&S aspects. Conclusions include: respondents consider H&S during the six stages of projects and on eighteen occasions more so during the downstream and midstream stages than the upstream stages, and respondents' knowledge is more extensive with respect to non-designer-related aspects than designer-related aspects. Recommendations include: respondents should consider H&S more frequently during the first three stages of projects and upstream occasions; project managers should adopt a multi-stakeholder approach, and construction H&S should be embedded in all tertiary built environment.

Keywords: *construction; health and safety; multi-stakeholders; non-compliance; roads agency*

1. Introduction

The 'Construction Health & Safety Status & Recommendations' report highlights the considerable number of accidents, fatalities, and other injuries that occur in the South African construction industry (Construction Industry Development Board (cidb), 2009). The report cited the high-level of non-compliance with H&S legislative requirements, which is indicative of a deficiency of effective management and supervision of H&S on construction sites as well as planning from the inception / conception of projects within the context of project management. The report also cited a lack of sufficiently skilled, experienced, and knowledgeable persons to manage H&S on construction sites.

The Construction Regulations, which constitute the primary regulations in terms of managing H&S in the South African construction industry, allocate a range of H&S responsibilities to clients, designers, quantity surveyors, principal contractors, and contractors (Republic of South Africa (RSA), 2014). Consequently, H&S in South African construction is a multi-stakeholder issue, and not just the responsibility of contractors. However, from a non-legislative perspective, the Construction Industry Development Board (cidb) (2009) states that decisions made by the team at all stages of the project affects the H&S of the entire project. From an international perspective, the Health & Safety Executive (HSE) (2006) states clients, employers, employees, designers, and contractors involved in the construction industry have a duty and responsibility to identify hazards and manage risks pertaining to H&S on sites and must take ownership of their part in the process. Proper planning and working collaboratively at all stages of the project will significantly reduce H&S risks and incidents / accidents on construction sites.

With respect to the role of clients in construction H&S, Musonda et al., (2012) propose a client-centered model to improve H&S performance, as a client’s H&S culture can positively influence contractors’ and designers’ H&S performance. The H&S culture of clients should be embedded in their H&S management system (HSMS). A good HSMS that defines leadership, involvement, commitment, communication, competence, and safe work procedures (SWPs) impacts positively on project H&S performance.

Given the status of H&S in South African construction, the requirements of H&S legislation and the functions of project stakeholders, and the status of H&S on a roads agency’s projects, including the occurrence of incidents and accidents on their projects, a study was conducted among the roads agency’s stakeholders, the objectives being to determine the:

- frequency at which respondents’ practices consider H&S during the six stages of projects;
- frequency at which respondents’ practices consider H&S on eighteen occasions;
- frequency at which respondents undertake nine H&S-related interventions on the roads agency’s projects;
- extent to which fourteen multi-stakeholder interventions impact on H&S;
- extent to which twelve interventions positively affect construction H&S, and
- respondents’ self-rating of their knowledge relative to twelve H&S aspects.

The objectives were evolved from the research gap in the form of the roads agency, the employer of the lead author, not being aware of the contributions of the respective multi-stakeholders’ H&S contributions and interventions on its projects, their impact, and the multi-stakeholders’ H&S knowledge.

2. Review of the literature

2.1. Stages of projects

Within the context of South Africa, the six stages of projects are: project initiation and briefing (stage 1); concept and feasibility (stage 2); design development (stage 3); tender documentation and procurement (stage 4); construction documentation and management (stage 5), and project close out (stage 6) (RSA, 2019). The six statutory built environment councils schedule the actions required of their respective registered persons per stage, H&S included.

2.2. H&S legislation and regulations

In terms of the South African Construction Regulations (RSA, 2014), clients are required to, inter alia, prepare an H&S specification based on their baseline risk assessment (BRA), which is then provided to designers. Designers in turn are required to, inter alia: consider the H&S specification; submit a report to the client before tender stage that includes all the relevant H&S information about the design that may affect the pricing of the work, the geotechnical-science aspects, and the loading that the structure is designed to withstand; inform the client of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is changed; modify the design or make use of substitute materials where the design necessitates the use of dangerous procedures or materials hazardous to H&S, and consider hazards relating to subsequent maintenance of the structure and make provision in the design for that work to be performed to minimise the risk. To mitigate design originated hazards, requires hazard identification and risk assessment (HIRA) and appropriate responses, which process should be structured and documented.

Thereafter, clients must include the H&S specification in the tender documentation, which in theory should have been revised to include any relevant H&S information included in the designer report. Thereafter, they must, inter alia: ensure that potential principal contractors (PCs) have made provision for the cost of H&S in their tenders; ensure that the PC to be appointed has the necessary competencies and resources; ensure that every PC is registered for workers' compensation insurance cover and in good standing; discuss and negotiate with the PC the contents of the PC's H&S plan and thereafter approve it; take reasonable steps to ensure that each contractor's H&S plan is implemented and maintained; ensure that periodic H&S audits and documentation verification are conducted at agreed intervals, but at least once every 30 days; ensure that the H&S file is kept and maintained by the PC, and appoint a competent person in writing as an agent when a construction work permit is required. To mitigate design originated hazards, requires HIRA and appropriate responses, which process should be structured and documented.

In addition to the abovementioned interventions required of contractors, contractors must identify the hazards and the risks to which persons may be exposed, analyse and evaluate the hazards and the risks using a documented method, and produce a plan and applicable safe work procedures (SWPs) to mitigate, reduce, or control the hazards and risks. This process is emphasised throughout the Construction Regulations, and although it is a continuing process, initial construction HIRA is initiated for and documented in the PC's H&S plan. A range of other interventions are required, inter alia: notification of intention to commence construction work; the appointment of a construction manager who is responsible for the management of H&S on a project; appointment of a full-time or part-time H&S Officer, which is a staff function in that it is an advisory role; conducting of medicals; appointment of competent persons to supervise specific activities such as excavations and scaffold erection and dismantling; scientific design of temporary works; provision of a fall protection plan where activities warrant same; training; provision of H&S information to workers; environmental monitoring; conducting of audits and inspections; record keeping, and storage and handling.

2.3. *Best practice client actions*

The Australian Federal Safety Commissioner's best practice client H&S principles emphasise client involvement in, and contributions to contractor H&S (Department of Education, Employment and Workplace Relations, 2008): developing an H&S culture in their own organisations and across the construction industry by including H&S as an integral aspect of project management, and affording H&S status equal to that afforded cost, quality, and time. Providing leadership and commitment by considering H&S at every level of decision making, referring to H&S standards in contracts, and monitoring H&S throughout all stages of projects. Developing cooperative relationships by facilitating the establishment of an integrated H&S project management team, and establishing long-term relationships with the supply chain. Promoting H&S in planning and design by including H&S in the design brief, selecting designers based on commitment to H&S, collaborating with stakeholders during design to ensure that H&S is considered, and overseeing H&S design reviews. Communicating H&S information to all project stakeholders in the supply chain, and managing H&S hazards and risks, and maintaining effective H&S measures across the project lifecycle.

2.4. *Procurement related H&S interventions*

Section 2.2 above addressed the procurement-related interventions required by legislation and regulations relative to H&S in South African construction. However, Wells and Hawkins (2011) published a briefing note directed at clients, financiers of infrastructure projects, and procurement agencies, arguing that procurement is a direct way for clients and financiers to make a "real difference" to H&S. They highlighted the following: the development of a clear client H&S policy and strategy to safeguard the H&S of workers on projects; the inclusion of H&S criteria relative to the selection of consultants; the conducting of a comprehensive H&S risk assessment in the early planning and design stages of a project; inclusion of client H&S objectives in tender documentation; pre-qualification of contractors in terms of H&S criteria; substantive reference to H&S on standard conditions of contract; evaluation of financial provision for H&S during tender evaluation; client monitoring of contractors' H&S and contractor reporting thereon, and post-project evaluation of a project's H&S.

2.5. *Promoting best H&S practice*

Fleming, Lingard and Wakefield (2007) record six principles in their 'Guide to Best Practice for Safer Construction' which was directed at the collective built environment in Australia and applicable to all levels, namely industry, organisation, and project: demonstrate H&S leadership; promote design for H&S; communicate H&S information; manage H&S risks; continuously improve H&S performance, and entrench H&S practices. The interventions per principle follow. Demonstrate H&S leadership: inclusion of H&S as a project value; management commitment to H&S; H&S communication; H&S leadership by example; visible H&S leadership and management H&S commitment on site; client project H&S objectives, and inclusion of H&S throughout the supply chain. Promote design for H&S: appointment of designers that are competent in terms of H&S and committed thereto; systematic design H&S reviews, and documentation and communication of residual risks. Communicate H&S information: development of a project H&S communication strategy; early communication of H&S information; "open and honest H&S dialogue" between all project stakeholders; continuous communication of H&S risk information to all stakeholders throughout the project, and 'bottom up' H&S communication courtesy of workers. Manage H&S risks: throughout all stages of the project; following of the hierarchy of risk control, however, elimination of risks is the ideal, and following of safe work procedures (SWPs) during construction. Continuously improve H&S performance: reviewing of H&S performance; development of leading and lagging key performance indicators (KPIs), and compiling 'lessons learnt' reports. Entrench H&S practices: large construction firms should provide leadership, and develop and mentor small and medium-sized enterprises (SMEs).

3. Research

3.1. Research method and sample stratum

The researcher selected a quantitative research method for the research study. A questionnaire was developed and distributed to fifty (50) roads agency stakeholders who were sampled using probability sampling. Forty-six (46) responses were received from a range of project stakeholders, which equates to a response rate of 92.0% - 30.4% were Construction Health and Safety Agents, 21.7% were Civil Engineers, 13.0% were Technologists, 8.6% were Construction Health & Safety Managers, 6.5% were Operational Health and Safety Agents, 6.5% were SHE Managers, 4.3% were Design Managers, 4.3% were Construction Project Managers, 2.2% Depot Managers, and 2.2% Resident Engineers.

'Microsoft Excel 2016' was used to process and analyse the primary data collected through the questionnaire survey. Closed-ended questions with five-point Likert scales, which included an 'Unsure' response option, were used. The analysis of the data entailed the computation of descriptive statistics in the form of frequencies, and a measure of central tendency in the form of a mean score (MS).

3.2. Research results

26.1% of the respondents had 0 - 10 years' experience in construction, and 47.8% 11 - 20 years. Only 26.1% had more than 20 years' experience. The mean years' experience was 17.9. Therefore, the respondents can be deemed to have had exposure to construction, which contributes to the reliability of the findings.26.1% of the respondents were older than 40 years of age, which cohort is described as 'older workers'.

It is notable that 50.0% of the respondents are in the age range 30 – 35, and 23.9% in the age range 36 – 40. The mean age of the respondents was 42.9 years. In terms of qualifications, BTech degree (37.0%) predominates, followed by Honours degree (21.7%), Bachelors degree (13.0%), and Masters degree (13.0%). Only 2.1% of the respondents have a doctoral degree. Therefore, the respondents can be deemed experienced and educated, which contributes to the reliability of the findings.

45.7% of the respondents were registered with the Engineering Council of South Africa (ECSA), and 32.6% are registered with the South African Council for the Project and Construction Management Professions (SACPCMP), which further contributes to the reliability of the findings.

Table 1 indicates the frequency at which respondents' practices consider H&S during the six stages of projects in terms of percentage responses to a scale of never to always, and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of

3.00, which indicates that in general, H&S can be deemed to be considered during the six stages frequently, as opposed to infrequently.

However, it is notable that 3 / 6 (50%) of the MSs are > 4.20 ≤ 5.00, and thus H&S can be deemed to be considered between often to always / always - construction documentation and management (stage 5), project close out (stage 6), and tender documentation and procurement (stage 4).

The remaining MSs are > 3.40 ≤ 4.20 and thus H&S can be deemed to be considered between sometimes and often / often - design development (stage 3), concept and feasibility (stage 2), and project initiation and briefing (stage 1).

The stages with MSs > 4.20 ≤ 5.00 are notable, as they represent stages 4 to 6, and the opportunity to influence construction H&S is greater during the early, than the latter stages of projects in the form of stages 1 to 3.

Table 1. The frequency at which respondents' practices consider H&S during the six stages of projects.

Stage	Response (%)						MS	Rank
	Unsure	Never	Rarely	Some-times	Often	Always		
Construction documentation and management (S5)	2.2	2.2	2.2	2.2	8.7	82.6	4.71	1
Project close out (S6)	0.0	0.0	8.7	2.2	6.5	82.6	4.63	2
Tender documentation and procurement (S4)	4.3	6.5	2.2	8.7	10.9	67.4	4.36	3
Design development (S3)	2.2	8.7	4.3	15.2	21.7	47.8	3.98	4
Concept and feasibility (S2)	2.2	10.9	4.3	17.4	28.3	37.0	3.78	5
Project initiation and briefing (S1)	0.0	4.4	15.6	22.2	26.7	31.1	3.64	6

Table 2 indicates the frequency at which respondents' practices consider H&S on eighteen occasions in terms of percentage responses to a scale of never to always, and MSs ranging between 1.00 and 5.00. It is notable that none of the MSs is below the midpoint score of 3.00, which indicates that in general, H&S can be deemed to be considered frequently, as opposed to infrequently.

It is notable that 5 / 18 (27.7%) of the MSs are > 4.20 ≤ 5.00, which indicates that H&S can be deemed to be considered often to always / always - site inspections, project progress meetings, site handover project status reporting, and preparing project documentation. It is notable that the top two ranked and forth ranked occasions are downstream, and the third and fifth ranked occasions are midstream.

12 / 18 (66.6%) of the MSs are > 3.40 ≤ 4.20, which indicates that H&S can be deemed to be considered sometimes to often / often. Compiling a project lessons learnt report is downstream, evaluating tenders is midstream, and the remaining occasions are upstream.

Table 2. The frequency at which respondents' practices consider H&S on eighteen occasions.

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Some-times	Often	Always		

Site inspections	0.0	0.0	2.2	0.0	17.4	80.4	4.76	1
Project progress meetings	0.0	0.0	4.3	0.0	17.4	78.3	4.70	2
Site handover	0.0	0.0	2.2	11.1	20.0	66.7	4.51	3
Project status reporting	0.0	2.2	4.4	8.9	33.3	51.1	4.27	4
Preparing project documentation	2.2	6.7	4.4	6.7	22.2	57.8	4.23	5
Compiling a project lessons learnt report	6.5	8.7	2.2	10.9	26.1	45.7	4.05	6
Client meetings	2.2	6.5	8.7	10.9	30.4	41.3	3.93	7
Project goals	0.0	6.5	8.7	21.7	13.0	50.0	3.91	8
Project initiation meeting	0.0	8.7	8.7	15.2	32.6	34.8	3.76	9
Considering project duration	2.2	8.7	8.7	15.2	37.0	28.3	3.69	10
Detailed design reviews	2.2	6.7	8.9	26.7	24.4	31.1	3.66	11
Client project resourcing discussions	0.0	6.5	15.2	17.4	28.3	32.6	3.65	12
Constructability reviews	4.4	8.9	8.9	20.0	28.9	28.9	3.63	13
Design coordination meetings	2.2	6.5	10.9	26.1	23.9	30.4	3.62	14
Evaluating tenders	2.2	10.9	21.7	10.9	13.0	41.3	3.53	15
Review of working drawings	2.2	13.0	8.7	26.1	19.6	30.4	3.47	16
Pre-qualifying contractors	2.2	10.9	19.6	19.6	13.0	34.8	3.42	17
Pre-tender meetings	2.2	10.9	19.6	21.7	17.4	28.3	3.33	18

Table 3 indicates the frequency at which the respondents undertake nine H&S-related interventions on the roads agency's projects in terms of percentage responses to a scale of never to always, and MSs ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the nine H&S-related interventions are undertaken frequently, as opposed to infrequently.

It is notable that only 1 / 9 (11.1%) of the MSs is > 4.20 ≤ 5.00, which indicates that the frequency is between often to always / always – construction management of H&S on the project. This finding is not unexpected due to the emphasis on managing H&S during the construction process.

However, it is notable that 4 / 9 (44.4%) of the MSs are > 3.40 ≤ 4.20, which indicates that the frequency is between sometimes to often / often - project management of H&S on the project, designing for construction H&S, client H&S resourcing of projects, and increased authority on H&S of projects.

The remaining 3 / 9 (33.3%) of the MSs are > 2.60 ≤ 3.40, which indicates the frequency is between rarely to sometimes / sometimes – project decision making, early planning of H&S, review of contractor financial provision for H&S, and monitoring insurance (provision and claims).

Table 3. The frequency at which respondents' practices undertake nine H&S-related interventions.

Intervention	Response (%)							
	Unsure	Never	Rarely	Some-times	Often	Always	MS	Rank
Construction management of H&S on the project	4.3	0.0	0.0	17.4	39.1	39.1	4.23	1
Project management of H&S on the project	6.5	2.2	4.3	23.9	28.3	34.8	3.95	2
Designing for construction H&S	4.4	4.4	8.9	17.8	33.3	31.1	3.81	3
Client H&S resourcing of projects	8.7	6.5	6.5	19.6	26.1	32.6	3.79	4

Increased authority on H&S of projects	6.5	10.9	6.5	26.1	15.2	34.8	3.60	5
Project decision making	4.5	6.8	13.6	29.5	25.0	20.5	3.40	6
Early planning of H&S e.g., Stage 1	4.3	6.5	15.2	28.3	26.1	19.6	3.39	7
Review of contractor financial provision for H&S	4.3	10.9	17.4	23.9	17.4	26.1	3.32	8
Monitoring insurance (provision and claims)	6.5	19.6	8.7	19.6	21.7	23.9	3.23	9

Table 4 indicates the extent to which fourteen multi-stakeholder interventions impact on H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, H&S can be deemed to be impacted by multi-stakeholder interventions on the roads agency's projects to a major, as opposed to a minor extent.

It is notable that all the MSs are > 4.20 ≤ 5.00, which indicates that the extent to which the fourteen multi-stakeholder interventions impact on H&S can be deemed to be between near major to major / major – supervision of the project, hazard identification and risk assessment (HIRA), project H&S management, project risk management, discussing of H&S matters in progress and technical meetings, management involvement in H&S, compliance with H&S legislative requirements, involvement in H&S from project initiation and briefing to project closeout, constant H&S communication, H&S education and training, H&S pre-qualification of contractors, adequate references to H&S in contract documentation, project partnering that includes H&S, project H&S programmes awareness, and promotion. The contribution of supervision should be noted, as well as HIRA, project-wide management of H&S, project-wide risk management, and discussing of H&S matters in progress and technical meetings.

Table 4. Extent to which fourteen multi-stakeholder interventions impact on H&S.

Intervention	Response (%)						MS	Rank
	Un-sure	Minor……………………Major						
		1	2	3	4	5		
Supervision of the project	0.0	0.0	0.0	8.9	17.8	73.3	4.64	1
Hazard Identification and Risk Assessment (HIRA)	0.0	2.2	4.4	0.0	24.4	71.1	4.62	2
Project H&S management	0.0	0.0	2.3	2.3	31.8	63.6	4.57	3
Project risk management	0.0	2.3	2.3	6.8	25.0	65.9	4.55	4
Discussing of H&S matters in progress and technical meetings	0.0	0.0	2.2	4.3	21.7	69.6	4.54	5
Management involvement in H&S	0.0	0.0	2.2	13.0	15.2	69.6	4.52	6
Compliance with H&S legislative requirements	0.0	0.0	4.3	8.7	19.6	67.4	4.50	7
Involvement in H&S from project initiation and briefing to project closeout	0.0	0.0	2.2	8.7	30.4	58.7	4.46	8
Constant H&S communication	0.0	0.0	2.3	9.1	34.1	54.5	4.41	9
H&S education and training	0.0	0.0	2.2	10.9	32.6	54.3	4.39	10
H&S pre-qualification of contractors	2.2	0.0	8.9	8.9	22.2	57.8	4.32	11
Adequate references to H&S in contract documentation	0.0	2.2	6.8	13.6	15.9	61.4	4.27	12
Project partnering that includes H&S	6.5	0.0	2.2	15.2	23.9	50.0	4.26	13
Project H&S programmes, awareness, and promotion	0.0	0.0	4.3	15.2	32.6	47.8	4.24	14

Table 5 indicates the extent to which twelve interventions positively affect construction H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major), and an MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the interventions / phenomena positively affect construction H&S to a major as opposed to a minor extent.

However, 7 / 11 (63.6%) MSs are > 4.20 ≤ 5.00, which indicates that the interventions positively affect construction H&S between a near major to major / major extent – adequate planning for construction projects, contract documentation that addresses H&S, comprehensive client H&S requirements, consideration of H&S by engineering designers, multi-stakeholder project H&S plan, contractor H&S programme, and constructability reviews by designers.

The remaining 4 / 11 (72.7%) of the MSs are > 3.40 ≤ 4.20, which indicates that the interventions positively affect construction H&S between some extent to a near major / near major extent – H&S pre-qualification of contractors, multi-stakeholder project quality plan, contractor programming, optimum project programme, and partnering.

Table 5. Extent to which twelve interventions positively affect construction H&S.

Intervention	Response (%)						MS	Rank
	Un-sure	Minor……………………Major						
		1	2	3	4	5		
Adequate planning for construction projects	2.2	0.0	2.2	4.3	19.6	71.7	4.64	1
Contract documentation that addresses H&S	0.0	0.0	0.0	8.7	23.9	67.4	4.59	2
Comprehensive client H&S requirements	0.0	2.2	0.0	4.3	15.2	76.1	4.57	3
Consideration of H&S by engineering designers	0.0	2.2	0.0	8.7	23.9	65.2	4.50	4
Multi-stakeholder project H&S plan	2.2	2.2	2.2	2.2	32.6	58.7	4.47	5
Contractor H&S programme	0.0	0.0	6.5	4.3	15.2	71.7	4.46	6
Constructability reviews by designers	4.3	0.0	2.2	8.7	32.6	52.2	4.41	7
H&S pre-qualification of contractors	0.0	2.2	4.3	6.5	28.3	56.5	4.26	8
Multi-stakeholder project quality plan	2.2	4.3	8.7	13.0	26.1	45.7	4.02	9
Contractor programming	0.0	2.2	10.9	17.4	23.9	45.7	4.00	10
Optimum project programme	0.0	10.9	8.7	10.9	19.6	47.8	3.78	11
Partnering	6.5	8.7	8.7	15.2	23.9	37.0	3.77	12

Table 6 indicates the respondents' rating of their knowledge relative to twelve H&S aspects in terms of percentage responses to a scale of 1 (limited) to 5 (extensive), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents rate their knowledge as above average.

It is notable that all the MSs are > 3.40 ≤ 4.20, which indicates that the rating is between average to above average / above average – project managing construction H&S, construction H&S, construction HIRA, contractor H&S specifications, financial provision for construction H&S, H&S plans, H&S pre-qualification of contractors, design hazard identification and risk assessment (HIRA), designer H&S specifications, designer reports (response to the H&S specification), and designing for H&S.

Table 6. Respondents' rating of their knowledge relative to twelve H&S aspects.

Aspect	Response (%)						MS	Rank
	Un-sure	Limited………………				…Extensive		
		1	2	3	4	5		
Project managing construction H&S	0.0	0.0	2.2	26.1	39.1	32.6	4.02	1
Construction H&S	0.0	0.0	6.5	26.1	28.3	39.1	4.00	2
Construction HIRA	2.3	2.3	9.1	25.0	18.2	43.2	3.93	3
Contractor H&S specifications	0.0	0.0	11.1	24.4	26.7	37.8	3.91	4
Financial provision for construction H&S	0.0	2.2	8.7	26.1	26.1	37.0	3.87	5
H&S plans	0.0	2.3	15.9	20.5	20.5	40.9	3.82	6
H&S pre-qualification of contractors	0.0	0.0	20.9	20.9	23.3	34.9	3.72	7
Design Hazard Identification and Risk Assessment (HIRA)	0.0	2.3	18.2	18.2	31.8	29.5	3.68	8
Designer H&S specifications	0.0	2.2	11.1	35.6	22.2	28.9	3.64	9
Designer reports (response to the H&S specification)	0.0	4.3	10.9	28.3	34.8	21.7	3.59	10
Designing for H&S	0.0	2.3	25.6	18.6	27.9	25.6	3.49	11

4. Conclusions

Given that 73.9% of respondents had 11 or more years' experience in construction, and the mean years' experience was 17.9 years it can be concluded that the respondents are experienced. Given the qualifications of the respondents, among other, B. Tech (37.0%), Honours (21.7%), Bachelors (13.0%), and Masters (13.0%), it can be concluded that the respondents are well educated. Consequently, given the experience and qualifications of the respondents, the findings can be deemed reliable.

Given the frequency at which respondents' practices consider H&S during the six stages of projects, it can be concluded that H&S is generally considered during projects, however, more so during the downstream and midstream stages than the upstream stages. Given that the opportunity to influence H&S is greater during the upstream than the downstream stages, the possibility exists that the potential to influence H&S downstream is not being capitalised on.

Given the frequency at which respondents' practices consider H&S on eighteen occasions, it can be concluded that H&S is generally considered during projects, however, more so during the downstream and midstream stages than the upstream stages. This conclusion is underscored by, among other, the MS and rank of 'compiling a project lessons learnt report' (4.05: 6th) versus that of 'constructability reviews' (3.63: 13th), and 'review of working drawings' (3.47: 16th).

Given the frequency at which respondents undertake nine H&S-related interventions on the roads agency's projects, it can be concluded that generally the H&S-related interventions are undertaken on the roads agency's projects. However, there is potential to increase the frequency relative to 'early planning of H&S' e.g., Stage 1, and 'review of contractor financial provision for H&S', which would enable further leverage of contractors' H&S by the roads agency.

Given the extent to which the fourteen multi-stakeholder interventions impact on H&S on the roads agency's projects, it can be concluded that construction H&S requires multi-stakeholder contributions. However, the top five ranked interventions amplify the importance of a project wide approach to H&S, the integration of H&S into all aspects of the project, project supervision, HIRA, and risk management, which leads to the conclusion that clients must provide H&S leadership, and emphasise the importance of such an approach.

Given the extent to which twelve interventions positively affect construction H&S on the roads agency's projects, the prior conclusion that construction H&S requires multi-stakeholder contributions is reinforced. Furthermore, it can be concluded that planning in general, and the procurement process play a major role in construction H&S.

Given the respondents' self-rating of their knowledge relative to twelve H&S aspects, it can be concluded that their knowledge is more extensive with respect to non-designer-related aspects than designer-related aspects as the latter are ranked within the last four and their MSs fall within the lower part of the related MS range. This leads to a further conclusion that the frequency at which respondents consider H&S during the upstream stages of projects and occasions, and the frequency of upstream interventions is attributable to a deficiency in related knowledge.

5. Recommendations

Stakeholders should consider H&S more frequently during the first three stages of projects as doing so raises the status of H&S on projects, creates awareness of and engenders potential multi-stakeholder contributions to H&S, especially on the part of the roads agency, project managers, and designers. Therefore, H&S should be integrated into all aspects of project management, and all interventions, meetings included.

Stakeholders should consider H&S more frequently during the upstream occasions, which are generally design-related, which will, among other, mitigate the occurrence of design-originated hazards. In this regard, the roads agency and project managers have a critical role to play. In addition to HIRA and risk management in general, being hallmarks of projects, H&S should be integrated into all interventions, including design coordination meetings, design reviews, and constructability reviews.

The roads agency and project managers should review and ensure adequate contractor financial provision for H&S, which impacts on the implementation stage of the project. However, this should be preceded and complemented by a comprehensive roads agency baseline risk assessment, roads agency provided H&S specification to the designers, designers' reports provided to the roads agency, roads agency provided H&S specification to the bidding contractors, and detailed reference to H&S in the contract documentation in the form of, among other, H&S preliminaries.

CPMs should adopt a multi-stakeholder approach in terms of the project management of H&S throughout all six stages of projects to engender consideration of H&S, and ideally, should evolve an integrated multi-stakeholder project H&S plan.

Construction H&S should be embedded in all tertiary built environment education, and professional association and / or statutory council accreditation panels should assess the status quo. Professional association and statutory councils should promote, and preferably, deliver H&S-related continuing professional development (CPD). Such interventions will contribute to mitigating a deficiency in H&S-related knowledge on the part of project stakeholders.

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"Building Risk" Modified Gaussian S-Curve

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Abstract:

Observing the projects in the implementation, it was determined that the management does not use risk management on a scientific basis. Apart from the abbreviated ISO documentation for plants within the construction company, there is no separate risk register documentation. By reviewing the existing documentation of the construction organization project and visiting the construction site by interviewing with the project management, the risk register of the given project was identified and defined. The quantitative method of simple assessment by management experience defines the attempt to manage risks by initial analysis. Defining planning with a modified Gaussian S curve (MGSC) and using the risk variable in a given method creates a probabilistic analysis of risk assessment with objective quantitative risk data on the project. Thus, the MGSC creates a sinusoidal prediction of the behavior of the occurrence of risk with the possibility of updating the behavior of the project in the life cycle. Further discrete quantitative risk identification at the activity level becomes an ongoing process in project management, primarily at the terms with the highest risk probability.

Keywords: *project risk management; risk register; quantitative risk analysis; modified Gaussian S-curve risk*

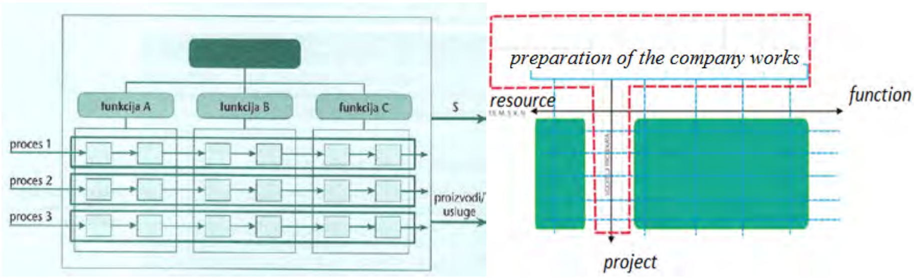
1. Introduction to building risks

The term "risk" is related to the probability of making a profit on a particular investment. In the case of projects, this is the degree of susceptibility of the project to probable adverse events (Medanić and Pšundre and Skendrović, 2005). Exposure to uncertainty (Ward and Chapman, 2003) and an adverse event that negatively affects the real requirements of project participants defines a specific risky event on the project. Risk events are stochastic events in the time variable and the intensity of the occurrence of an adverse event at that time. The current intuitive project management (MP) and management of business systems (MBS) are trying to turn the third and fourth industrial revolutions into scientific management. Thus, the former born leader of the right hemisphere of the brain manages intuition and manages the mass of data with synthetic thinking and rounding off the integrity of the data. Therefore, the monitoring of the project with financial data at the levels of the entire facility has been reduced to a unit of project measure m3, m2, m', kg, and other flexible measures and works quite well in all systems. Such data is considered credible for quick and easy management, and based on experience, project progress is predicted, but for different projects, a deceptive picture is created in the course of the project, which leads to business losses. Therefore, science wants to manage business scientifically, rationally and rationally, rather than emotionally, and tries to define risks in management. Companies are rapidly introducing an integrated information system (IIS), and building information modeling (BIM) (Yin and Qian, 2013) to computerize and accelerate construction and business processes to minimize risks. New process management methods and Japanese quality improvement methods At this level, Kaizen or (Total Quality Management-TQM) and Kanban or just now (Just in Time-JIT) provide process management of the system and, at this level, establish controls and regulator managers based on knowledge (Lean Management-LM). This is how Business Process Reengineering (BPR) is created, i.e., through creative management of companies using probabilistic statistical models of project management with the aim of sustainable transformation of the company. Experience to date proves that despite all the scientific achievements in project and process management, the riskiness of projects does not cease, especially in the first cycles of new project implementation. The risk arises as a result of the uncertainty of the event or the emergence of unreliability in the state of the process events. That is, the risk arises as a consequence of the threat (Buntak and Drožđek and Košćak, 2014) and it is difficult to meet the timeliness of fitting into the planned costs and deadlines of the project. Sources of risk include macroeconomic variables (prices, interest rates, exchange rates) that affect costs as well as microeconomic variables within the project (human resources), especially today when there is no workforce and potential liabilities with uncertain events (legal and operational). Weakness in predicting certain types of errors, such as human errors, business technical and operational errors, and legal market macroeconomic and political situations, was identified in all industries. In construction production, there are various proposals for defining the model of the risk register system (Burcar and Radujković, 2005; Okoye and Okolie and Odesola, 2022), while the quantification of risk is approached with a series of simulations in BIM tools with a risk application (Ali and Alhajlah and Kassem, 2022). . The research is mostly global, and there is a need to analyze the details of the project. As a result, risk importance and ranking are assessed quantitatively, qualitatively, and combinatorially. The list of risks that are analyzed at some stage of the construction project is created by adding a list of risks related to the project to the list of risks that are common to all construction projects. The main problem is that company management uses the risk management method too little, especially from a scientific point of view. The first problem is the lack of definition of the risk register, except for a handful of ISO documents for a couple of risks at the company's facilities. Then, the problem in defining risk is the subjectivity of the quantitative method of defining risk. The research question boils down to a more detailed definition of risk by project activities and an attempt to determine or quantify risk in order to avoid the subjectivity of management. The contribution of the paper is the creation of a risk register by the method of interviews and brainstorming with the management of the company and the project, and the quantification of risks using the MGSC. The objectives of risk registers in project activities are to encourage a different way of defining risk using existing registers and to use mathematical probability statistical methods. Then the development of new models and the creation of standardization for simulations in project management with ranks to increase the likelihood and impact of positive events and reduce the impact of negative risks on the project.

2. Situations in which risk management in project processes

2.1. Project and organization management

Project Management (MP) (Andrijanić and Gregurek and Merkaš 2016; Horine, 2009) takes place through three, four, or five managerial functions with continuous decision-making that is constantly burdened with risks as an uncertain event or condition that may occur in the future and disrupt one project goal , time, financial, or qualitative, and reduce it to tolerant risk. The organization of the industrial manufacturing society has dominated for two and a half centuries and is only now being replaced by the information society. However, organizational structures do not follow the rapid change of technology and the theory of scientific management (SM). Nevertheless, hierarchical structures have been created (Widhiastuti, 2012) that impose process control by levels of management and the formation of network structures as organizational or technological components. Network structures, on the other hand, create virtual and federal organizational structures such as corporations that include all their main participants in their structure (Belak, 2014), which is conducive to the development of a globalizing economic structure. The postmodern organization (Sikavica, 2011; Križaić and Rodiger and Buč, 2021) begins with the introduction of information technology and defines the organization systematically and procedurally (Figure 1). A systematic approach is defined by general system theory and strives to ensure that all system resources are in the function of environmental dynamics and feedback or control. All this is based on information that, with the classical vertical hierarchical flow, passes to the horizontal process flows of communications. This is how addiction theory emerges from system input resources.



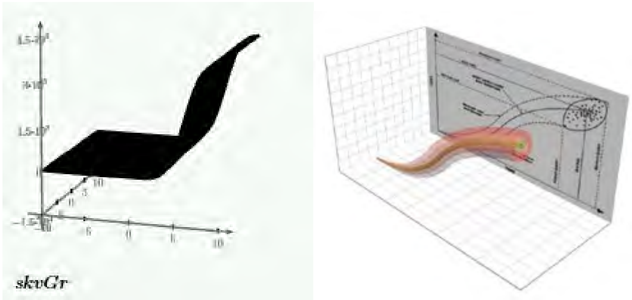
a) *b)*

Figure 1. System-process and vector organization (Sources: (a) Organization, Sikavica, 2011, (b) Informatized manager in vector organization, Kriai, Rodiger, and Bu, 2021).

2.2. Project management with MGSC

Recently, probabilistic forecasting of project performance and the use of stochastic S-curves with a software package for generating stochastic S-curves and a simulation approach showed a dispersion deviation from the S-curve according to the Gaussian function of cost-time distribution density. Expected Monetary Value (EMV) diagrams are now popular and complemented today with functional 3D-MGSC (Križaić and Hranj, 2019; Križaić et al., 2021)) (Figure 2).

$$skvGr(x,T) = \lambda kv \cdot \int_0^x \frac{1}{(a \cdot T + b) \cdot \sqrt{2 \cdot \pi}} \cdot e^{\frac{-(x-\mu)^2}{kv \cdot (a \cdot T + b)}} dx \tag{1}$$



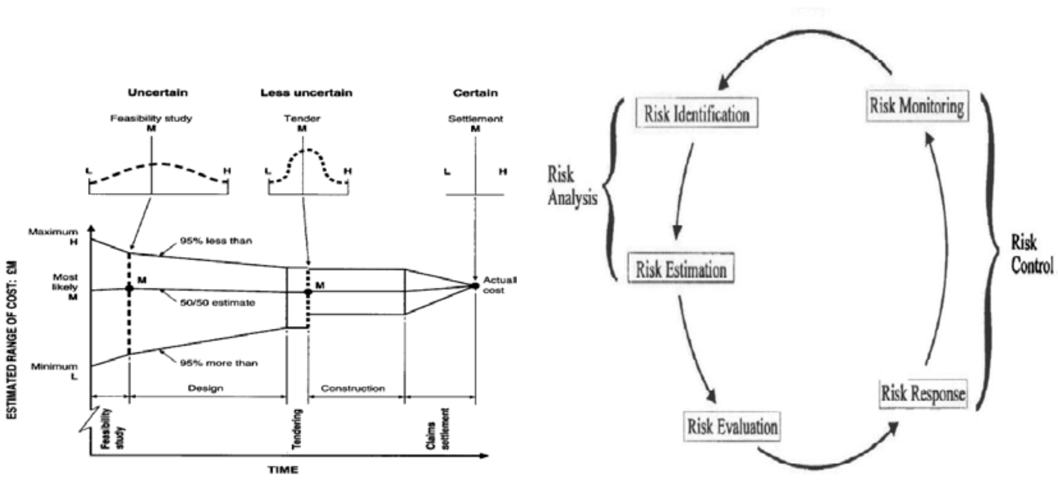
a) b)

Figure 2. 3D-MGSC project (source: a) Project Planning by Modified Gauss S-Curve, Križaić and Hranj, 2019, b) Simulation project management using the Modified Gauss S-Curve, Križaić et al., 2021)

Leveling and matching of curves, i.e., modification of the Gaussian curve, refers to the introduction of a constant kv parameter in the value of 10000 units.

2.3. Risk management in processes

The construction business is very vulnerable to risks, and manufacturers are interested in business risks, which can be internal or external. Investments or construction projects in their "rocket" evolution (Godfrey and Halcrow and Partners Ltd, 1996) go through several phases (conceptualization, definition, execution, and maintenance of projects) (Figure 3).



a) b)

Figure 3. Cyclical risk management flow (source: (a) Control of risk and guide of systematic risk management from construction, Godfrey and Halcrow and Partners, 1996, (b) A framework for process-driven risk management in construction projects PhD , Cerić, 2003)

It is evident that risks can be qualitatively and quantitatively defined with a scale from avoidance to acceptance of risk with a given risk response. Risk analysis and control, i.e., risk identification and assessment through project regulation, goes through a cyclical process. Then, at the beginning of the 21st century, the planning and control of the cost center of a capital-oriented company shifts to a knowledge-oriented company that wants to have information in a single virtual information base and add productivity to value-added companies (EVA) or market value-added value added (MVA). As Japanese and American process control in business production processes have developed standards for product quality management, so has the general framework of risk management standards published by various organizations around the world (ISO, IEC, etc.). Thus, the risk management process was set according to the ISO/IEC 31000 standard (Krakar, 2014), which was created for all operations from risk identification to risk acceptance with analysis and evaluation, and risk assessment and management through risk monitoring and consulting.

3. Qualitative methodology risk register

Risk analysis includes the identification and assessment of risk. Methods can be qualitative or quantitative with a variety of risk management techniques. The purpose of the analysis is to compile a list of risks relevant to a particular project. Through interviews and forecasting with project management, risk was defined and identified at the level of project activities.

3.1. Identifying the risk register

There are many risk analysis structures. Thus, risks can be technical, external, organizational, and managerial (PMI, 2011). The key is the identification of resources or activities in the construction project that are subject to threats or vulnerabilities in the project itself. Risk identification methods are: brainstorming or brainstorming, interviews, surveys, Delphi or cyclical consensus techniques of decision-making experts (Cerić, 2016) and expert systems as techniques that contribute to optimal decision-making in project implementation. While today, the identification or analysis of risk is based on historical databases of the risk register with qualitative and quantitative data for given projects in all process groups of the MP.

3.2. Qualitative risk assessment and evaluation

Complementing qualitative risk analysis is a quantitative method. It can be done on the basis of experience and on the basis of a database of former projects to assess and evaluate the risk of the project empirically or by mathematical methods. The concept of utility, on the other hand, plays a central role in deciding economic indicators on a project with a simple risk assessment. Based on experience, the project manager gives a percentage of the expected event to individual activities or risks. The communication technique for obtaining the data for a given method is the simplest interview with the project management. Risk assessment in decision making in the development of risk information takes place through two phases. The initial phase with the risk analysis procedure defines the scope of the risk assessment, while in the second phase, the risk management procedure makes decisions on the control of unacceptable risks.

3.3. Risk registry table

The project manager should structure the process in project and identify risk factors or weaknesses in the project and the company through the organizational cycle of the construction project process. An initial risk register for a given project was determined by a request from the company's management, commercial and work preparation, and project management. Thus, the analysis of the causes of opportunities and threats and the reaction to the threats given by the brainstorming method and interview is defined (Table 1).

Table 1. Register of construction project risk within a construction company

FAZA	IZVORI funkcijski	IZVORI u projektima nositelji – resurs	PRIJETNJA SIMPTOMI i ZNAKOVI upozorenja	Sekundarni uzrok rizika	POSLJEDICA				dogovore odgovor na rizik
					TROŠAK	t	Q	KVALITETA	
Projektiranje	Proizvodnja	projektna dokumentacija	Nepotpunost i nedorečenost dokumentacije naručitelja investicije	nivo projekta	>	>	>	<	osigurati kvalitetne projektant
			TROŠKOVNIK Nepreciznost i nestandardnost opisa stavaka	nedefinirano st kvalitete proizvoda	>	>	>	<	osigurati kvalitetne projektant

4. Quantitative risk analysis of MGSC

Mathematical, statistical, and simulation modeling methods are used to quantify the risk of MGSK in simulating the financial condition of the project over the course of the project. Based on previous research, an attempt to supplement the risk parameter (λkvr) with an investment of 30% MGSC proved to be too much for the observed project. Risk structuring according to the activities of the project plan with regard to the probability of deviations from the planned cost values of the project is done by the method of simple assessment of site management. Then, the risk management process on a given project is defined by the MGSC method, and according to the time distribution, the risk is distributed by activities based on the Gantt chart of the given project.

4.1. MGSC risk analysis

By dividing the MGSC of a given project into time tithes, the probability of their difference or risk in a given segment is obtained. The data show that the process obtains the Gaussian deviation distribution function, and the expectation E (x) and the dispersion D (x) can be defined. The results of tens of the plan curve skvGr and the realized skvGrr from a given project are given graphically (Figure 4) based on equations (2, 3, 4 and 5).

$$skvGr(x,Tp) = \lambda kvp \cdot \int_{(n-1)\cdot\frac{t}{10}}^{n\cdot t/10} \frac{1}{(a\cdot Tp+b)\cdot\sqrt{2\cdot\pi}} \cdot e^{\frac{-(x-\mu)^2}{kv\cdot(a\cdot Tp+b)}} dx \qquad n \in 1..10 \qquad (2)$$

$$skvGrr(x,T) = \lambda kvr \cdot \int_{(n-1)\cdot\frac{t}{10}}^{n\cdot t/10} \frac{1}{(a\cdot T+b)\cdot\sqrt{2\cdot\pi}} \cdot e^{\frac{-(x-\mu)^2}{kv\cdot(a\cdot T+b)}} dx \qquad n \in 1..10 \qquad (3)$$

$$driz = skvGr(x,Tp) - skvGrr(x,T) \qquad (4)$$

$$Rizik\% = driz * 100 / \sum_{i=0}^{9} driz \qquad (5)$$

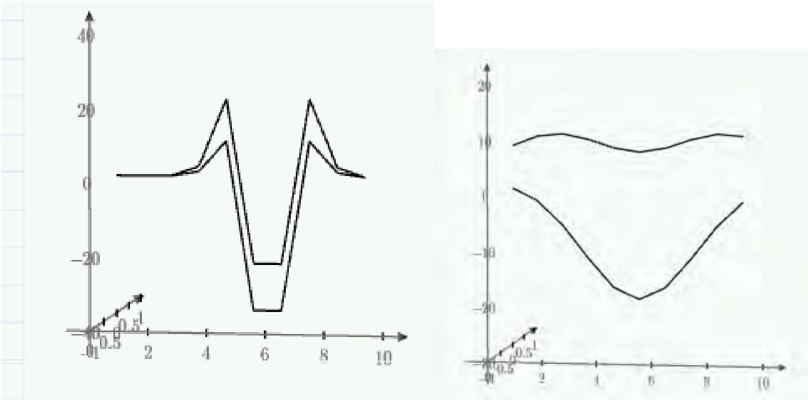


Figure 4. Monthly risk percentage (plan-real) on projects-using the MGSK method

Defining the extension of the project duration also envisages an increase in the project cost by λr of the risk parameter, which is added to the standard MGSC parameter λkvp. Thus, the MGSC plan is entered with max. and the average risk given on the project by the distribution of max. from 24% for activities from 6 to 12%, which gives an increase in the project price of over half a million kuna (Figure 5) with λr = 1.11 (6).

$$kvsGr(x,T) = \lambda r \cdot \lambda kvp \cdot \int_0^{x+\Delta t} \frac{1}{(a \cdot Tp+b)\cdot\sqrt{2\cdot\pi}} \cdot e^{\frac{-(x-\mu)^2}{kv\cdot(a\cdot Tp+b)}} dx \qquad (6)$$

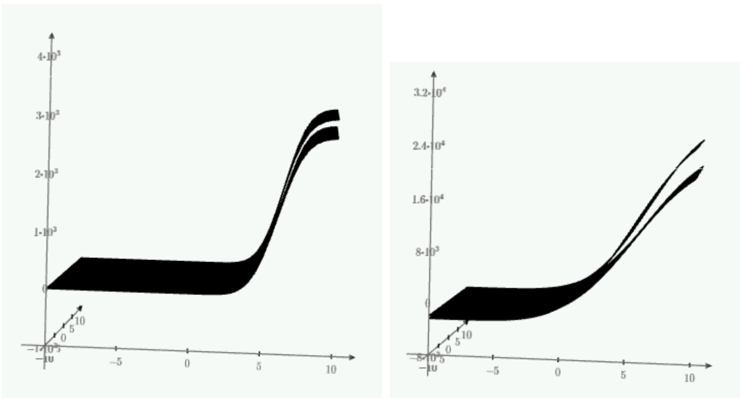


Figure 5. Estimated MGSK projects (plan-real)

The given estimate of the annex to the contracted amount was realized after the completed situation and almost coincides with the risk estimate of the parameter λr = 1.11 or 11% increase in the price of all project activities.

4.2. Register by MGSC

However, Table 2, defined from the Gantt chart of a given project, shows a supplement to the risk analysis with a simple risk assessment by activities of 1 to 7% increase in the price of activities with a total of 100% distribution, which is price within the project annex. While the MGSC's risk-sharing (8) by activities ranges from 6 to 12%, it also reaches a total of 100% on certain activities.

Table 2. Register of construction project risk by project activities

FAZA	IZVORI funkcijski	IZVORI u projektima nositelji_resurs	PRIJETNJA SIMPTOMI i ZNAKOVI upozorenja	Sekundarni uzrok rizika	POSLJEDICA TROŠAK	t	Q	KVALITETA	dogovoreni odgovor na rizik	Prihvatljivost	PRIORITET razina rizika visoki	srednji	niski	Identificiran RIZIK Unutarnji	Vanjski	aktivnosti izvođenja	kvantitativna prognoza % rizika u anexu	prognoza Po realizaciji % rizika u anexu	plan RMGSK % vjerojatnosti
Projektiranje	Proizvodnja	projektna dokumentacija	Nepotpunost i nedorečenost dokumentacije naručitelja investicije	nivo projekta	>	>	>	<	osigurati kvalitetne projektante	DA	x			X			14	5	0
			propust	IZMJENE pozicija	>	>	>	>	ažuriranje POG	DA	x			X		ZIDARSKI RADOVI	0	1	6
			propust	NEISPORUKA ili zastoj RESURSA	>	>	>	<	promjena dobavljača, nadzor konstruktera izvođača	DA		x		X		AB RADOVI dilatacija B,E, priz. I kat ab. Strojarnica i recepcija	0	0	6
			propust		>	>	>	<	sanacija	DA		x							
			propust	OTVORI-PROBOJI	>	>	>	<	kvalitetni izvođač i resurs	DA	x					IZOLATERSKI RADOVI			11
			loša kontrola	poddimenzionirane instalacije	>	>	>	<	sanacija i osiguranje od šteta	DA		x		X			0	2	
			loša kontrola	veze	>	>	>	<	kvalitetni izvođač i resurs od istog proizvođača	DA	x					FASADERSKI RADOVI	3	3	11
			loša kontrola		>	>	>	<	sanacija	DA			x			SOBOSLIKARSKO LIČILAČKI RADOVI	0	1	12
			loša kontrola	red tehnologija	>	>	>	<	sanacija	DA		x				PARKETARSKI RADOVI	0	2	12
			loša kontrola	nesavjesnost kooperanta	>	>	>	<	sanacija	DA	x			X					
			loša kontrola	linije	>	>	>	<	sanacija	DA		x				KERAMIČARSKI RADOVI	0	2	12

This shows that with a little scientific effort in companies, we can avoid the problem of the risk register being undefined. While the problem of subjectivity for the research question of trying to determine or quantify risk by activity has a logical component in addition to functional values.

5. Conclusion

The qualitative method of interviews and brainstorming and random selection of construction sites shows the results that can serve to further supplement the risk register within a given company and serve management to use new modern methods of business management. The quantitative method is defined by the idea of defining the project plan by MGSK and dividing the project into term tenths and considering the difference between the plan and the reality of the project as a substitute for risk. This turns out to be logical because the defined data also coincides with other natural processes that mainly take place according to the laws of the Gaussian curve. By observing the MGSK risk density curves, it is evident that the risks vary like a wave, with an increase at the beginning of the introduction of activities into the project and at the end of the project. The curve, in addition to being mathematical, is also in accordance with the logic of project execution. The risks are clear that during the initial introduction of many subcontractors and in the final phase, there are almost always delays in the activities of the project, which also creates density, speed and greater risk, as well as the possibility of an accident at work. For the safety of the hypothesis, interview and brainstorming methods are not enough to generalize risk, and it is necessary to process several cases with an appropriate database that would determine the size of probability, i.e., risk coefficient λr and thus direct calculation of risk impact on duration, cost, and quality. It is recommended to further research the database of implementation and planning projects in order to realistically obtain the risk ratio or λr and strive to create a creative team manager in corporate security with the competencies of IT managers (Šarčević, 2016) who has a new tool for defining risk in business projects. This, in turn, strives for the sustainability of the artificial intelligence business model (AR) (Shan, 2019) with cyber physical processes (CPS), i.e., a system for initiating new discoveries in defining the development of technology and organizational standards in MP. Risk assessment by management experience is complemented by the MGSC. From the ratio of planned and realized coefficients λkvp and λkvr of the MGSC equation, the risk coefficient λr was developed. This coefficient increases the value of the S-curve and easily estimates the amount of risk in the project relative to the plan. This connection with the random numbers on the RMGSC creates a simulation of project development according to possible risk scenarios in relation to the cost variable, which is similar to the JRAP method used by MCS on the time variable.

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Risk Management in Water Management Projects Co-financed by the European Union

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Abstract:

The risk management system ensures that the objectives of the project are more likely to be met and also ensures that possible damage or loss is avoided or reduced. In addition, effective risk management enables better decision-making, better planning and optimization of available resources, addressing priorities and avoiding problems that may arise during the project life. In projects co-financed by the European Union through the Competitiveness and Cohesion Program, risk management is regulated and formalized through mandatory rules, guidelines and procedures. The roles, tasks and responsibilities of all project participants are clearly defined. The paper presents a risk management system in projects co - financed through the Competitiveness and Cohesion program in water management sector of the economy. All procedures and steps from risk identification to risk response and control are presented and explained. The risk management system in the management and control system and especially at the level of operations is especially explained. A risk management plan as well as a risk register have to be elaborated for every project. Risk registers are kept separately by projects and overall for the whole portfolio. Special attention is paid to the risk response strategy. The practice has shown that the described risk management system has proven to be successful in dealing with project risks and useful in overall project management. With minor adjustments, the presented system can be applied to other projects, not only those co-financed by the European Union.

Keywords: *risks; risk management system; risk management activities; risk register*

1. Introduction

"Organizations of all types and sizes face internal and external factors and influences that make it uncertain whether and when they will achieve their objectives. The effect this uncertainty has on an organization's objectives is "risk". All activities of an organization involve risk " (ISO 31000:2018).

Common National Rules (ZNP 2020) define risk as a potential threat, event (or totality of events), activity (or totality of activities), or omission, which may cause irregularities, ineligibility of expenditures, the need to make financial corrections or loss of reputation of the *Management and Control System* body (MSC 2021) and may be a threat successful performance of the functions assigned to them or a threat to the efficient functioning of the system as a whole. Missed opportunities are also considered as risks, and these are situations when the competent body or the responsible person has not taken the measures / actions that it was obliged to take in accordance with the applicable rules.

The risk management system ensures that the objectives of the project are more likely to be met and ensures that damage is avoided or reduced. Managing risks means thinking in advance about potential events that may occur, the effects and consequences that the project may face in the future, and take timely measures to minimize risks, and thus avoid or reduce adverse effects. Effective risk management enables better decision-making, better planning and optimization of available resources, addressing priorities and avoiding problems that may arise in the project.

Every event that can affect the achievement of project results has its own probability of occurrence. On the other hand, such an event can result in consequences for the project. The consequences depend on the project's exposure to a particular risk event. Consequences are a negative or positive effect on at least one of the project parameters: cost, time, scope or quality.

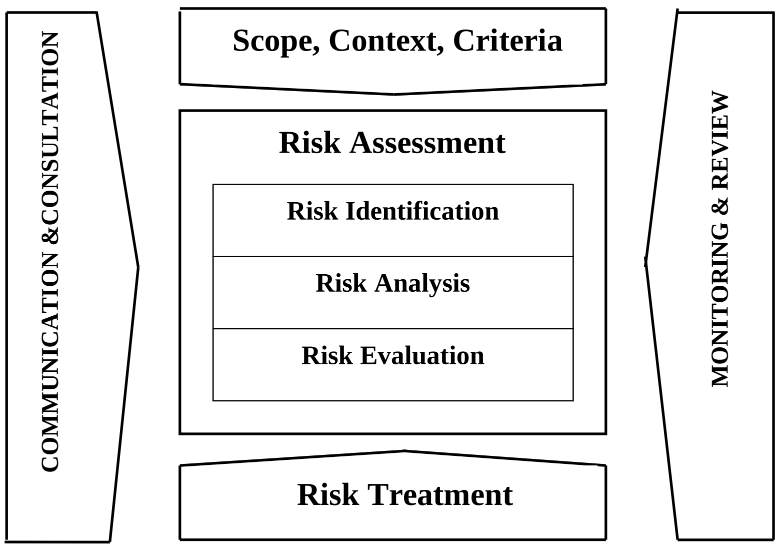

Figure 1. Risk Management Process (ISO 31000:2018)

Risk is a combination of the probability of a risk event and its consequences on the project, in other words the project's exposure to that event:

$\boxed{\text{Risk = probability of a risk event * project exposure to risk}}$

If both components, uncertainty and exposure, are not present - there is no risk.

The most important advantages of risk management are:

- Readiness to anticipate problems instead of reacting to them only when they arise
- As much as and whenever possible, preventive measures are used
- The underlying causes are addressed, not just the symptoms
- A structured and repeatable problem-solving process is applied.

Risk management leads to the identification of risks and responsibilities in terms of how they are managed and ensures that project risks are proactively analyzed, processed, regularly monitored and controlled.

2. Risk Management Process in the Framework of EU Programme Competitiveness and Cohesion

In the projects co-financed by the European Union through the *Competitiveness and Cohesion Programme* (EU programme), risk management is regulated and formalized through mandatory rules, guidelines and procedures. The roles, tasks and responsibilities of all project participants are clearly defined.

The risk management process in the European Union's *Competitiveness and Cohesion Programme* is explained in the *Common National Rules* (ZNP 2020) specifically in the Rule 10 titled Risk Management.

Rule 10 consists of ten annexes with procedures, instructions and forms:

Annex 1: Map of procedural risks
Annex 2: Catalog of risk types
Annex 3: Risk Register
Annex 4: Risk Mitigation Action Plan
Annex 5: Instructions for the preparation of Annex 6
Annex 6: Assessment of exposure to specific risks of fraud
Annex 7: Recommended mitigation controls for fraud risks
Annex 8: Fraud indicators - public procurement and consulting services
Annex 9: Indicators of suspected fraud
Annex 10: Tool for self-assessment of risk exposure to ineffective and inefficient irregularity management

Rule 10 of the *Common National Rules* (CNR) further explains:

- Missed opportunities are also considered risks, and these are situations when the competent body of the MCS or the responsible person has not taken the measures / actions that he was obliged to take in accordance with the applicable rules. In this regard, the basic purpose of risk management is to improve the performance of the MCS body in relation to the systematic identification, assessment, management and control of risks and situations that may adversely affect the achievement of their objectives.

- The aim of risk management activities is to reduce the risks of individual MCS bodies to an acceptable level, by implementing measures that will mitigate (reduce) the possibility of risks, the effect of their implementation or both at the same time.

- Acceptable risk is the degree of risk that the project management is willing to accept in an effort to meet objectives. This means that the level of "acceptable risk" should be weighted in each case.

- Risk management is one of the five interrelated components of internal control, and the other components are: control environment, control activities, information and communication and monitoring.

Rule 10 of the CNR applies to the staff of bodies involved in the management and implementation of operations financed by the Competitiveness and Cohesion ESI Funds, but not to the end beneficiary of the project. This Rule includes a set of instructions issued by the Managing Authority for the purpose of establishing standardized risk management within the bodies of the Management and Control System (MCS 2021). The M*anaging Authority* in Republic of Croatia is the Ministry of Regional Development and *EU* Funds.

The bodies of the MCS are:
CT: Coordinating Body
CA: Certifying Authority
GB: Governing Body
IB1: Level 1 Intermediate Body
IB2: Level 2 Intermediate Body
AA: Audit Authority

Note: The Level 2 Intermediate Body for all water management project financed by European Union in Republic of Croatia is *Croatian Waters*.

Each MCS body systematically identifies and assesses risks that may jeopardize the achievement of the body's objectives, identifies and takes measures to mitigate the identified risks and monitors the development of identified risks.

Systematic and regular risk identification and assessment is the cornerstone of the risk management system, performed by the following MCS bodies: CA, GB, IB1 and IB2 - each reviewing its own activities, identifying related risks and ensuring risk management.

In this context, the following categories of risk management can be distinguished:

a) Risk management at the level of management and control system - risk management is a management function and within the risk management at the MCS level. Each MCS body systematically identifies and assesses risks that may jeopardize the achievement of the body's goals, identifies and takes measures to mitigate risks and monitors the development of identified risks.

b) Risk management at the level of operations - risk assessment at this level is based on sampling controls related to specific tasks of the MCS body, ensuring efficient use of operational program funds, in cases where 100% checks are not practical in terms of effectiveness. This applies to management checks carried out by IB2, eg. on-the-spot checks with beneficiaries, *ex ante* public procurement checks or checks based on sampled expenditure items in the reimbursement request, and described in the CNR Rule 5 - Execution and management of grant agreements.

c) Risk management related to the implementation of delegated functions - in this case it is a risk assessment of IBs performed by the GB in the performance of supervision over delegated functions.

3. Steps of the Risk Management Process

The project risk management process defines activities that serve to identify, assess, prioritize, manage and control risks that may affect the execution of the project and the achievement of its objectives. Given that a large number of risks arise in each project, management is normally focused on a set of selected key risks that have both high probability and high consequences. According to previous experience, the selection of 5-10 key (critical) risks is considered to be the basis of any successful project management.

The process of risk management is divided into four steps as follows.

3.1. Risk identification

The purpose of this step is to facilitate the identification and documentation of risks that may affect the project objectives. Risks need to be continuously identified throughout the project, but it is important to identify project risks as early as possible in the early project phase. The focus of the identification is on defining a list of key risks that have the greatest impact on the planned project objectives.

It is possible to use different risk identification techniques. The techniques which can be used to identify the risk can be as follows:

- Questionnaires
- Interviews with project stakeholders
- Brainstorming
- Monthly project meetings
- Workshops
- Risk checklists
- Risk lists from past projects

3.2. Risk assessment

The purpose of this step is to assess the likelihood and impact of the identified risks in terms of their impact on the project objectives. This assessment is necessary before any risk response planning can be done.

Risks are assessed based on their likelihood of occurrence and impact on project objectives. The product of their probability and their impact defines the level of risk, which is then used as a basis for prioritizing risk and determining appropriate response measures.

The level of risk will be calculated by combining the probability and impact of risk according to the example in Table 1:

Table 1. Risk probability and impact matrix

		IMPACT				
		1 = very low	2 = low	3 = mediate	4 = high	5 = very high
PROBABILITY	5 = very high	5	10	15	20	25
	4 = high	4	8	12	16	20
	3 = mediate	3	6	9	12	15
	2 = low	2	4	6	8	10
	1 = very low	1	2	3	4	5

Legend:

	Risks are acceptable. Risk plans can be developed.
	Risks cannot be accepted, risk response strategy should be developed (avoid, reduce, transfer / share)
	Unacceptable - Immediate response to risk reduction or avoidance
	Project acceptable risk acceptance limit (defined in the agreement of the Beneficiary with IB2)

Probability can be:

- Very low: less than 5% of the probability of occurrence;
- Low: between 5% to 10% of the probability of occurrence;
- Moderate: between 10% to 25% of the probability of occurrence;
- High: between 25% to 50% of the probability of occurrence;
- Very high: more than 50% of the chance of occurrence.

The impact can be:

- Very low: less than 1% of the financial value of the project and/or all component of the project are not affected, and/or a small number of affected individuals; with the ability to respond easily and quickly and solve problems.

- Low: 1% to 2% of the financial value of the project and/or low impact on several components of the project and/or affected only one project milestone, and/or negligible impact on every stakeholder in the project; with sufficient project-level competence to address the issue (if risk arises).

- Medium: 2% to 5% of the financial value of the project and/or medium impact on some components of the project and/or one or more affected project milestones, and/or several project stakeholders will be affected to some extent and/or project objectives may be affected, and/or there is a formal complaint; with limited project competencies to address the issue (if risk arises).

- High: 5% to 10% of the financial value of the project and/or high impact on some components of the project and/or several affected key stages, and/or several stakeholders in the projects will be affected and/or project objectives will be affected, and/or there are formal and legal complaints; with insufficient internal project competencies to address the issue (if risk arises).
- Very high: more than 10% of the financial value of the project and/or very high impact on several components of the project and/or several key project milestones and/or stakeholders in projects will be very affected, and/or the whole project will be affected or/and there are significant formal and legal complaints; external competencies are needed (which the project beneficiary does not have) to address this issue (if there is a risk).

The risk level thresholds are:

- Green: risk level <= 2;
- Yellow: risk level> = 3 and <= 16;
- Red: risk level> = 20.

After defining the initial Risk Matrix (Smjernice, 2017), the project beneficiary will define the values of the risk thresholds based on his ability and ability to accept a certain level of risk that he is willing to accept.

3.3. Risk response

The purpose of this step is to select a strategy for the best risk response and to identify and plan the necessary risk control steps and activities. The choice of risk response strategy will be based on the results of risk assessment (risk level), type of risk, effects on overall project objectives with special emphasis on project duration and project costs, total costs required by risk reduction strategy, and analysis the best possible options if there are several possible approaches to risk reduction. The strategy selected for each risk is documented in the Risk Register (Smjernice 2017). There are four possible strategies to be implemented: mitigation, avoidance, transfer or sharing, and risk acceptance.

- Avoidance: Take planning actions to direct execution to variants that do not involve the occurrence of the risk in question. Very effective, but also very limited possible applicable answer.
- Mitigation: Taking actions that reduce the likelihood or reduce the impact of risk when it occurs. A very common measure in practice.
- Acceptance: Acceptance of risk (impact / loss is accepted if risk occurs). It is used mainly for risks with low probability and / or low impact. With the risk-taking option, there are two possible reactions:
  - Acceptance of risk when no special action is required, except to continue to monitor risk (passive acceptance);
  - Acceptance and development of risk response plans (active acceptance).

- Transfer / sharing: Risk transfer or risk sharing with other entities, for example through insurance, subcontracting, partnerships, etc. Used for risks that cannot be managed by any of the parties involved in the project.

After selecting a strategy for each risk, specific measures for the implementation of the strategy will be defined, described, planned and delegated to individual stakeholders who should take responsibility for their implementation.

Specific activities as well as final results will be documented in the Risk Register. For the most important risks, it is essential to determine the dates by which the necessary activities will be carried out, as well as the assessment of the needed resources for its implementation. Risk response actions are documented and updated in the Risk Register throughout the project life cycle.

Table 2 shows the application of different risk response strategies to different project scenarios.

Table 2. Examples of risk response strategy

Scenario	Risk response strategy
Very high impact and high or very high probability or high or very high impact and very high probability	Avoidance or implementation of mitigation measures
Very high impact and very low probability	Transfer/share
All other levels of risk	Reduction
Low or very low probability and very low impact or very low probability and low impact	Acceptance

After submitting the initial proposal of the Risk Register, the project beneficiary will determine the escalation threshold X.

Risk escalation is defined in the following steps:

- All new risks, proposed risk response strategies and proposed measures are confirmed by the project manager, if the risk level is < X;
- All new risks, proposed risk response strategies and proposed measures are confirmed by the project beneficiary, if the risk level is > = X
- Depending on the risk, higher risks of greater importance will be reported to the project beneficiary. This usually refers to the risks that have a very high impact on the project, and the medium or higher probability of the event.

If the risk is escalated, it will be marked in the Risk Register with a special mark.

3.4. Risk control

The purpose of this step is to monitor and control the implementation of risk responses and continuously monitor the possibility of new risks or changes in existing identified risks.

Regular monthly meetings on the status of project implementation will also serve to review the status of risks and related activities and to identify new risks that may affect key project points, results or project objectives. Updating the Risk Register may include adding new risks or actions, updating the status of activities to reduced risk, changing the level of risk based on mitigation measures, changing tasks and responsibilities for assigned tasks, and so on.

4. Risk Management Procedures in the Water Management Projects

4.1. Risk management roles and responsibilities

The planning of risk management activities is performed by the project manager and documented in the Risk Management Plan (HV Priručnik 2015). The project manager may, if necessary, delegate specific activities for filling in and monitoring the Risk Register, as well as delegate special person (s) who will be in charge of monitoring the risk mitigation activities. Also, in the case of a large and/or particularly complex project, the project manager may delegate the risk management activity to a specific person whose task will be the overall risk management. Regardless of the delegation of responsibilities, the overall responsibility for risk management always remains with the project manager.

In addition to the project manager and the person in charge of risk management, a special risk team may be formed, as a special body headed by the risk manager or as an ad hoc group in charge of analysing all identified risks and monitoring risks until they are closed, that is, until the end of the project. This is recommended for large projects (eg. value greater than 100m EUR).

4.2. Risk management plan at the project level

Risk Management Plan identifies sources of risks and severity, likelihood of occurrence and controllability assessment, risk responses and adjust the plan and managing events that may have a positive or negative effect on project’s development and sustainability. It defines and documents the risk management processes in the project. It describes how to identify and assess risks, what tools and techniques will be used, relevant roles and responsibilities, how often risks need to be updated, etc. The Risk Management Plan also defines the process of monitoring risks and their escalation, as well as the structure of the Risk Register used to document and communicate risks and measures for their mitigation. Once released the risk management plan will remain a living document during the whole project duration.

The purpose of this document is:

- structuring the risk approach and processes to be used for the project;
- determining the role and responsibilities related to risk management;
- determining the methodology, standards, tools and techniques that will be used to support risk management.

The Risk Management Plan should include the following chapters:

1. Introduction

2. Objectives of risk management
3. Description of the risk management process
4. Roles and responsibilities of persons involved in risk management
5. Tools and techniques
6. Risk register
7. Risk identification activities
8. Risk analysis assessment
9. Risk escalation process
10. Risk response strategy
11. Risk control activities

4.3. Risk register

Risks need to be continuously identified throughout the project, but it is important to identify project risks at the earliest stage possible. As the project can be formally monitored within the MCS only after its approval, so are the requirements that IB2 may set to the project beneficiary, including the requirement to develop a Risk Management Plan and risk identification, related to the date of signing the Grant Agreement. It is important to point out that the project beneficiary should have already made the initial risk identification well before the formal approval of the project, and at the latest when filling in the application forms.

After the signing of the Grant Agreement, it is necessary to create an initial Risk Register (Smjernice 2017) after a field visit to the site where the project will be implemented and after interviews with all relevant project stakeholders, but no later than the start of work. Any other approach would not lead to a comprehensive view of project risks and could as a result lead to the wrong focus, misidentification of project risks and consequent application of inappropriate mitigation measures.

All identified risks must be entered in the Risk Register. The Risk Register consists of fields with associated options. The Risk Register needs to be updated at least once a month. Updating the Risk Register may include adding new risks or actions, updating the activity status to reduced risk, changing the risk level based on mitigation measures, changing tasks and responsibilities for assigned tasks, etc. The Risk Register is kept for each project separately and needs to be consolidated at the level of the entire portfolio.

4.4. Risk control activities

The project manager monitors and controls the risks in order to:

- identifify new risks by the project team or other stakeholders in the project;
- propose new ways to address risk (adding / changing measures);
- implement any of the previous measures or general events or events that will change the values of the probability and/or impact of the identified risks;
- make other changes.

Risk control additionally includes the following activities:

- Risk monitoring and control activities are complementary to the monitoring of the Risk Register, ie. the update of the Risk Register can follow only after the update of the situation and measures taken for each of the identified risks. The Risk Register should list the implemented measures and the state of risk after the implemented measures within the section "Risk Assessment after Response to Risk"
- Based on the developed Risk Management Plan and the initially developed Risk Register, the project manager proposes a person or several of them who will be in charge of monitoring each individual risk and taking the necessary steps identified in the Risk Register to be taken. The person in charge of a specific risk will periodically report on the risk status and all activities undertaken and inform the project manager, and will update the relevant parts of the Risk Register related to the indebted risk on a monthly basis.
- One of the items on the agenda of the monthly project coordination meeting should be a review of the Risk Register, which would analyze the identified risks and propose response measures. Risks will be reviewed at regular monthly intervals, but also after the occurrence of any event that could have a significant impact on the project environment and therefore project risks

4.5. Central risk register

The IB2 risk coordinator maintains the IB2 project portfolio Risk Register (Hrvatske vode 2016) The risk coordinator will be in charge of collecting and processing the Risk Register by each individual project, and their consolidation at the level of the entire IB2 portfolio. The risk coordinator will also have the task of harmonizing possible different approaches to risk identification on projects, compared to other projects. For this purpose, if necessary, a risk panel can be organized, where the joint work of the head of the Risk Register and the project manager in front of IB2 would achieve a harmonized approach to risk identification and analysis.

At the project portfolio level, a central Risk Register is maintained, in which all relevant data delivered by projects are consolidated and have general applicability and relevance. Project level data comes in the form of Excel spreadsheets/forms. After reviewing the form, it will be forwarded to the project management system, so that it will automatically load this data and consolidate it in the database. Until an automated data entry system is in place, it will be necessary to manually transfer data to a spreadsheet.

The IB2 project portfolio level Risk Registry needs to be updated at least once a month after the Risk Registers collected from each individual project have been submitted and after each Risk Register has been reviewed and verified by the project manager in front of the IB2. The risk register will be updated as necessary, when requested by the responsible bodies of the MCS or other competent authorities.

The structure of the Risk Register at the portfolio level corresponds to the risk structure at the project level with the necessary additional columns to identify each of the projects and contracts, and to simplify and facilitate grouping of risks by types, contracts and projects.

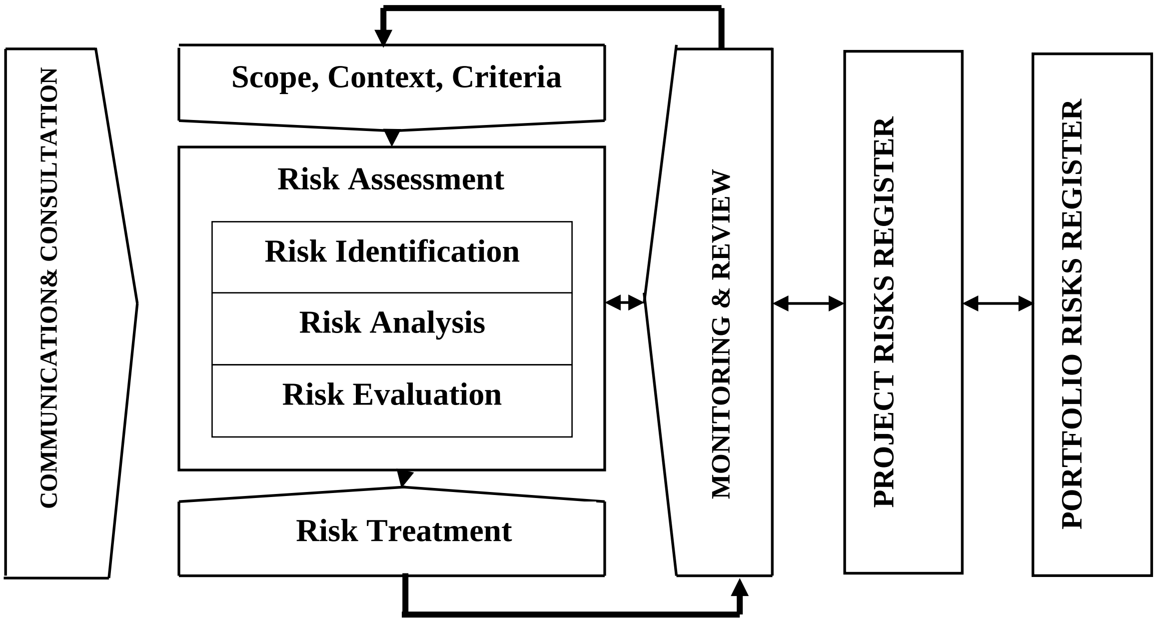

Figure 2. Central Risk Register at the portfolio level

The Risk Register on various portfolios will serve IB2 as an important tool for successful portfolio management.

Since the usability of each register, including the Risk Register, is directly dependent on the quality of the submitted information, the Risk Register is submitted together with the monthly report on the state of project implementation and must correspond to the actual state of the project.

4.6. Risk response strategy at the portfolio level

The risk response action is documented by the risk coordinator at the IB2 level and updated in the Risk Register throughout the project life cycle (EU PCM 2004).

The strategy for responding to risks at the level of the entire project portfolio includes overlapping with the Risk Register prepared at the level of the MCS in accordance with Rule 10 of the CNR, and in particular activities related to risk reduction and transfer/sharing, as these activities may include broader aspect of necessary interventions that do not exclude changes in certain procedures and manuals followed by all MCS bodies, adding new procedures, drafting other planning and programming documents, and even changing certain legal solutions.

5. Conclusions

The risk management procedures applied to EU co-financed projects are very detailed, supported by clear mandatory guidelines for implementation and control as well as defined organizational and personal powers and responsibilities.

The practice has shown that the herewith described risk management system has proven to be successful in dealing with project risks and useful in overall project management. With minor adjustments, the presented system can be applied to other projects, not only those co-financed by the European Union.

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Artificial Intelligence and Advanced Robotics Techniques in Healthcare Construction Projects

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Abstract:

Artificial intelligence is now part of our everyday lives – and its growing power is a double-edged sword, it is very gladly implemented in all branches of industry. However, the construction industry is very specific; it still resists the maximum use and application of artificial intelligence. Previous research based on research on the positive and negative impacts of the use of artificial intelligence and robotics in the implementation of construction projects has encouraged the development of further ideas on how the use of artificial intelligence and advanced robotics can improve design and implementation of medical facilities. The paper describes the ways in which AI and advanced robotics improve all phases of design and improve the implementation of medical projects. This research gives the idea and inspiration to propose the application and use of artificial intelligence and advanced robotics in the process of healing people.

Keywords: *automatization; advanced robotics; construction projects; healthcare buildings*

1. Introduction

Artificial intelligence (AI) together with related technologies is increasingly used in all branches of industry, even in healthcare. Artificial intelligence (AI) together with robotics has a high application, not only on the industry, also on the daily life activities that are performed. There is a huge potential from the application of these technologies that is waiting to be used and applied. AI is a field of computer science, which is capable of copying human characteristics, capacity of learning, and storage of knowledge. It executes human brain tasks in most of the fields in all aspects of our daily life using big data applications (Yang et al. 2021). Many stressful situations and activities today can be replaced with AI, thus improving life and our environment. Although there is a great fear of AI, many believe that one day it could replace a human, but the fact is that it greatly facilitates life and activities. AI should be seen as a tool to improve and facilitate life. Many life-threatening situations and activities can be automated and executed with the help of robotics and AI. Super computers are analyzing big data using the algorithms of advanced deep learning machines, which has allowed the improvement of output in the field. This field has led very needy and tremendous enhancement in every field of life, especially in healthcare (Yang et al. 2021).

1.1. Use of Artificial Intelligence (AI)

With the extensive adoption of artificial intelligence (AI), construction engineering and management (CEM) and architecture, engineering & construction (AEC) and is experiencing a rapid digital transformation. Currently, artificial intelligence (machine learning, neural network, deep learning, robotic), information security, big data, cloud computing, internet, and forensic science are all hotspots and exciting topics of information and communication technology (ICT) (Oludare 2018). If we look at the application of AI in the world, we can say that the potential of AI application is not fully used. Figure 1. shows Extent of AI adoption in EU MS, and Figure 2. shows Average monthly AI search volume (2016-2020).

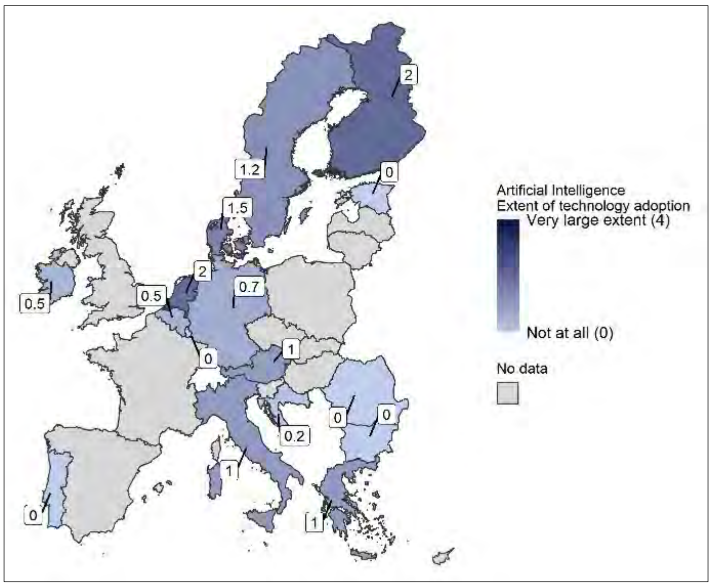

Figure 1. Extent of AI adoption in EU MS (source: Google trends, 2020)

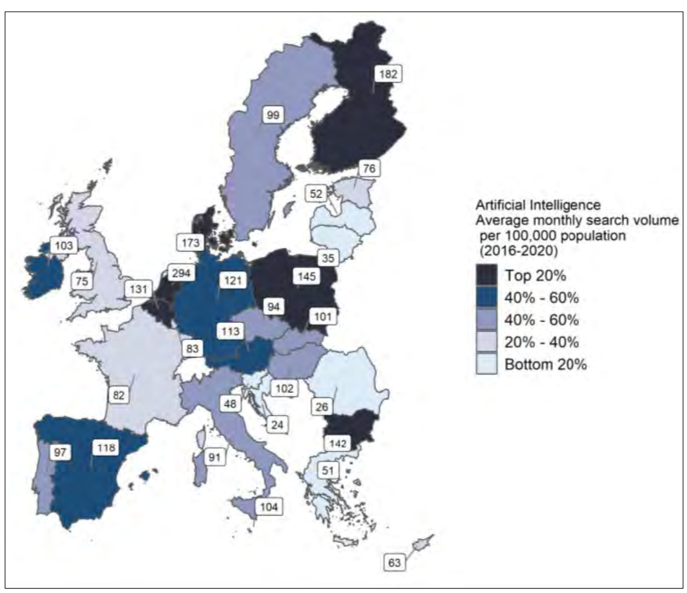

Figure 2. Average monthly AI search volume (2016-2020) (source: Google Ads, 2020)

1.2. AI in healthcare buildings

Artificial intelligence (AI) and related technologies are increasingly prevalent in business and society, and are beginning to be applied to healthcare. These technologies have the potential to transform many aspects of patient care, as well as administrative processes within provider, payer and pharmaceutical organizations (Chan et al. 2018). In addition to its use in the treatment of patients, the use of Artificial Intelligence (AI) is becoming more common in the construction of facilities. Especially because it speeds up the processes, reduces the time needed to complete the work, which directly affects the reduction of costs. Many activities performed on the construction site are repetitive activities, automation and use of AI provides control over these activities and the minimum time required to perform these activities. In most cases for public facilities, mostly facilities intended for the treatment of people, it is necessary to build them in a very short time, which is usually difficult or almost impossible to comply with the available workforce. The application of AI together with robotics can dramatically affect and solve at least some of these problems.

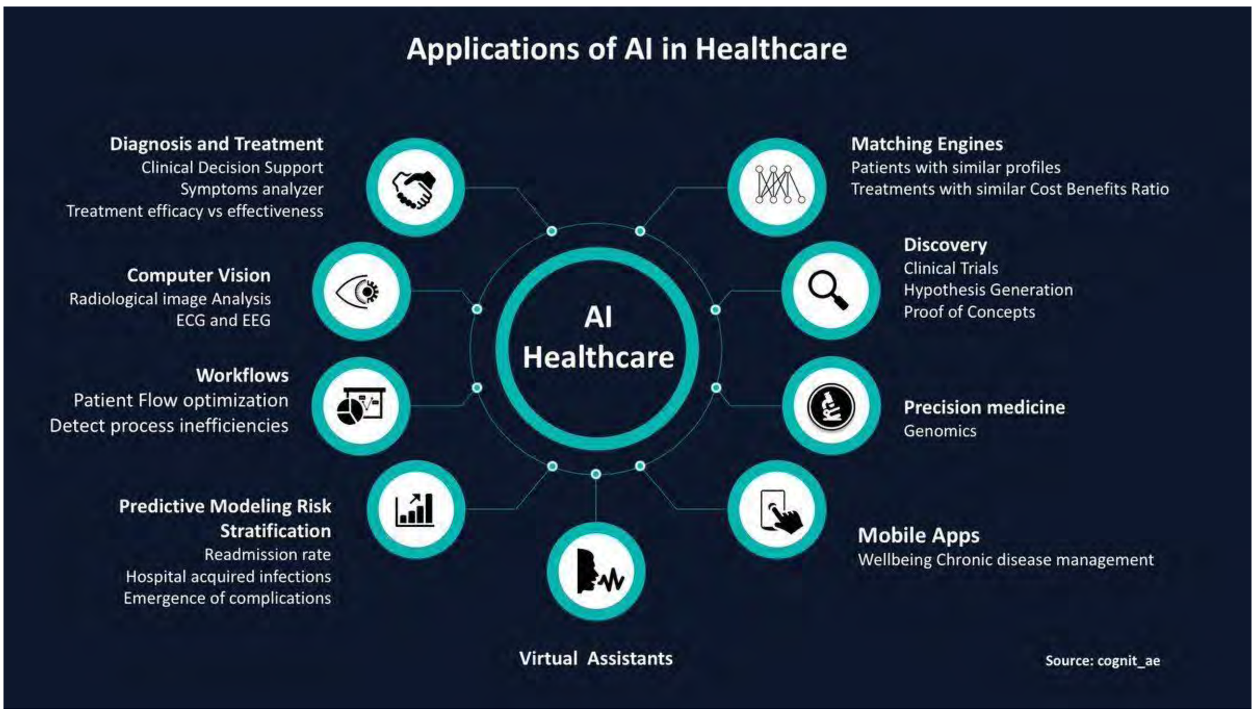

Figure 3. AI in Healthcare (source: https://www.pinterest.com/pin/537335799288893982/ May 2022)

In healthcare, the most common application of traditional machine learning is precision medicine – predicting what treatment protocols are likely to succeed on a patient based on various patient attributes and the treatment context (Lee et al. 2019). Just like performing work, the process of healing people can be raised to a higher level and improved by using AI. Artificial intelligence (AI) is becoming part of our life, its application raises people's awareness to a higher level, also it makes life much easier. Many of the activities that human perform can be much simpler and more productive using artificial intelligence.

1.3. Use of Robotics

Robots and intelligent machines enhance productivity, precision, and safety at the construction site. Remote-control systems and 3-D-model guidance enable advanced levels of automation (comparable to computerized numerical control in manufacturing)—for excavators, mobile cranes, and dump trucks, for instance (Gerbert 2016). Use of robots (construction robots, drones, autonomous vehicles, 3D printing and exoskeletons), the effect of averages and activities on the construction site is improved. The use of construction robots is becoming more and more used in developed countries, they can be involved in performing certain tasks, such as masonry, painting, loading, transport and bulldozers or excavators. The implementation of robots contributes to the protection of workers, as construction work is often a dangerous environment. Also, robots are largely replacing skilled worker, and it is common knowledge that a shortage of skilled worker is a global problem. Robotics and automated systems have the potential to revolutionize and provide many advantages to the construction industry and to the Architecture, Engineering and Construction (AEC) area. Construction is a labour-intensive sector. Robotic systems and automation have proved to be highly effective in other sectors for reducing labour costs while improving productivity and quality (Delgado 2019). The application of robotics in construction can be diverse. (Delgado 2019) The types of automation and robotic technologies for construction can be grouped in four general categories:

- Off-site prefabrication systems
- On-site automated and robotic systems
- Drones and autonomous vehicles
- Exoskeletons.

The first construction robots were developed in Japan to increase the quality of building components for modular homes (Bock 2007). The latest developments have been robots and autonomous vehicles for inspection, monitoring, maintenance, etc. (Delgado 2019) Drones, autonomous vehicles and Exoskeletons are an indispensable part of the use of robotics on construction sites because of the service they perform.

1.4. Advantages of AI and Advanced Robotics in healthcare construction project

Use of robotics in construction should be the replacement of people working in unhealthy or dangerous environments. Autonomous robots are particularly useful for replacing human workers performing dirty, physically difficult and unsafe tasks, thus avoiding exposure and reducing physical, ergonomic and psychosocial risks. Advanced robots and AI are already performing repetitive and monotonous tasks, handling radioactive material, or working in an explosive environment and perform many other repetitive, risky, or unpleasant tasks in various sectors such as agriculture, construction, healthcare, fire protection and the like. The cooperation between humans and robots will change over time and increase their autonomy by taking on a whole new form. To the use of robots on real construction sites to be effective, robots would have to be able to move with a certain degree of "intelligence", which means providing them with the means to climb and master various levels on the ground. It is therefore necessary to manage these Big Data, correctly, to be able to derive rigorous and reliable interpretations;

especially since there are advanced techniques and technologies that can be adopted to deal with Big Data problems (Philip Chen 2014). The application of advanced robotics and AI in construction projects is equally important in all phases of a construction project life cycle. AI and Advanced Robotics to have been able to be applied in all phases of the project, the project must be done in such a way that absolutely all segments are harmonized, it is best that it is in accordance with the BIM (Building Information Modeling). The phases of the construction project are as follows:

- Project Initiation and Conception.
- Project Planning and Definition.
- Project Execution and Launch.
- Project Performance.
- Project Close.

By applying AI and advanced robotics continuously from the first to the last phase of the project, it gives its maximum impact and potential.

1.5. Benefits of AI and Robotics for Healthcare

AI in medical diagnostics and decision-making is one of the top use cases, because AI can process large amounts of data in a short time, provide high reliability and speed of diagnosing and consider secondary conditions, such as genetics, lifestyle and environment. The American Cancer Society states that the use of artificial intelligence enables mammogram analysis that is 99% reliable and 30 times faster, significantly improving care outcomes (Shaptunova 2021). According to that, the benefits of AI for Healthcare are as follows:

- High quality of patient's lives
- High accuracy of treatment
- Reduces costs
- Higher employee engagement with patients
- Streamlined workflows
- High employee efficiency
- Decreased labor demand
- Reduce workload
- Enhanced protection against cybercrimes.

AI in healthcare is the emulation of human cognition and reasoning by complex algorithms in order to automate, scale and enhance processing, analysis, interpretation and comprehension of healthcare data and augment human activity (Shaptunova 2021). Artificial intelligence is not one technology, but rather a collection of them. Most of these technologies have immediate relevance to the healthcare field, but the specific processes and tasks they support vary widely (Davenport & Kalakota 2019). The use of robots in medical institutions is not unknown, it is even highly preferably, precisely because of the complexity of the activities performed there. The Robots have become more collaborative with humans and are more easily trained for a preferable task, they are also becoming more intelligent, as other AI capabilities are being embedded in their system. Physical robots are well known by this point, given that more than 200,000 industrial robots are installed each year around the world. They perform pre-defined tasks like lifting, repositioning, welding or assembling objects in places like factories and warehouses, and delivering supplies in hospitals (Davenport & Kalakota 2019).

2. Healthcare Construction Project – The University Clinical Centre of Serbia

The University Clinical Center of Serbia is an academic medical Center located in Belgrade, Serbia. The project has 106688.96 m2, divided into two phases; the total height of building is 51m, and the total number of floors is Teh+Po+Np+P+12+Teh.

- Above ground (Level -1/+13) 81,836.61 m2
- Below ground (Level -2) 16,500.83 m2
- Technical Level (Level -3) 8,351.52 m2

The first phase has 65,100 m2 this phase of the Project represents the Final Detail Design of the Project for the Addition, Reconstruction and Adaptation of the Clinical Centre of Serbia in Belgrade, and the second has 41,589 m2. Each phase is divided into a tower and a podium. The phases are determined so that individual units can function until the second phase is completed. It is an old construction of the building, to which a new project has been adapted. However, during the construction process there were changes that were inevitable, which significantly affected the further course of construction. A large number of participants, engineers, contractors and subcontractors have been great effort achieved and have made this project complete with minimal delays and problems. The first major impact on the projects was the impact of COVID-19, which stopped most of the work, but also the employees. Despite this impact, it was not only on the construction industry but also on all branches of industry and on all life activities, perseverance, work and respect for the recommended measures, helped to achieve maximum effect in such situations. The exposure of corona virus disease 2019 puts an increasing burden on the healthcare system (Yang et al. 2021), not only the health system but also the construction industry, which has undergone many changes, one of the highest impacts of COVID-19 was to suspend production, which led to a shortage of materials but also to an increase in prices. The contractor's position was in a very problematic situation, which was all not good for him, but also for the user. The project was supposed to be completed, but the deadline for completion was drastically moved. The delay was inevitable. All with the aim of completing the project and adequately fulfilling the task, all forces were instructed to complete the project and prevent further delays and risks that could occur. Further changes in the project were influenced by changes in the user and the requirements of the equipment that needed to be installed, which also indicated the postponement of the completion of works, but by increasing the workforce by 100% postponement of the deadline was prevented. A modification to the design of medical facilities are not uncommon, especially since so many rules and laws must be included and adhered to throughout the process, the Planning and Building Act is constantly amended and influenced and requires additional changes and adjustments to the project. All the changes that happen afterwards are very difficult to follow. Frequent situations are that the many things are forgotten, lost or not noticed. The question is whether all these changes would be much easier to follow with AI and Advanced Robotics. Research has been conducted; the participants in the survey were engineers of various professions, who are participants in the UCCS project. The survey involved 38 respondents, of which there were:

- 34,20 % Architects
- 36,80 % Civil Engineers
- 7,90 % Mechanical Engineers
- 21,10 % Electrical Engineers

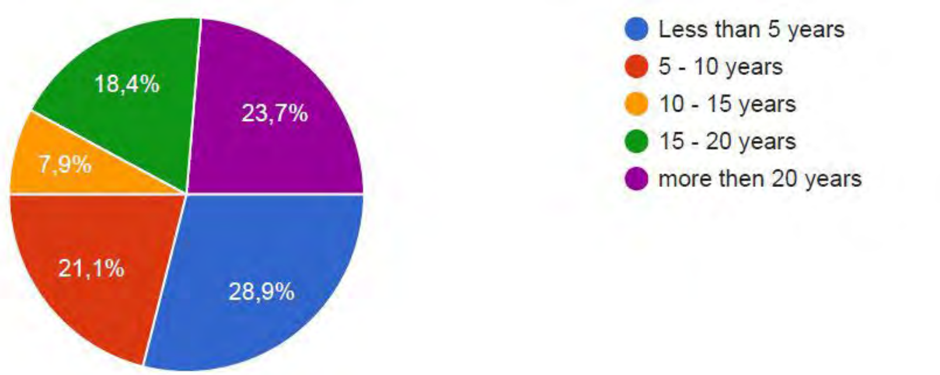

Figure 4. Engineering profession of Survey Participant

The survey participant's years of experience are shown below on Figure 5. The most of Participants have experience less than 5 years, right after them are the survey participants who have more than 20 years' experience.

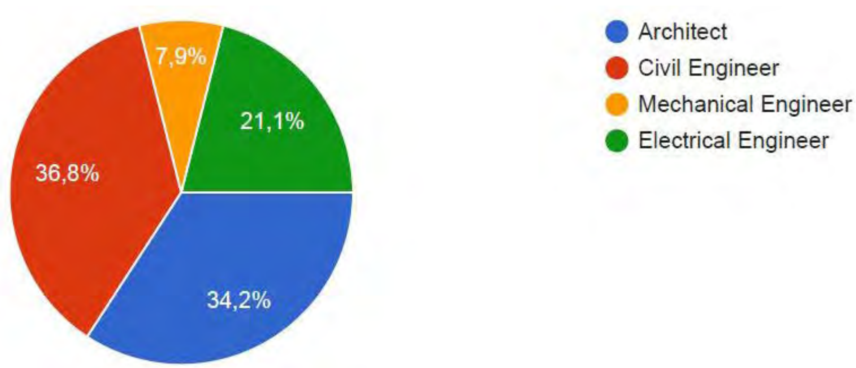

Figure 5. Survey Participant - years of experience

2.1.Results of survey

The survey was sent to 45 engineers - participants in the project, to the survey responded 38 participants. The Question: Sort a list according to the impact on the flow of healthcare project construction (from the largest to the smallest): 1. Frequent design change during the construction phase 2. Contractors' financing 3. Payment delay 4. Lack of contractors' experience 5. Poor cost estimation 6. Poor tendering documents 7. Poor material management; of the 37 respondents, 33 gave complete answers, while 5 had to be excluded from the survey due to incomplete answers, the answers are shown below in the table 1. The most participants (42,42%) put on the first place on the list for the largest impact on the flow of project - Frequent design change during the construction phase, and the other extreme is the impact of Poor material management with 45,45% at the last place. Project changes during the construction of healthcare facilities are becoming more common. In most cases, the changes effect on the flow of project construction, extend the deadline, complicate construction and make project management more difficult. Project management and monitoring changes are often a hard-working process, often leading to data loss or forgetting.

Table 1. Sort a list according to the impact on the flow of healthcare project construction

Impact	First place	Second place	Third place	Fourth place	Fifth place	Sixth place	Seventh place
1. Frequent design change during the construction phase	42,42%	6,06%	9,09%	6,06%	12,12%	21,21%	3,09%
2. Contractors' financing	9,09%	12,12%	18,18%	27,27%	18,18%	9,09%	6,06%
3. Payment delay	6,06%	33,33%	24,24%	18,18%	9,09%	3,03%	6,06%
4. Lack of contractors' experience	15,15%	18,18%	21,21%	21,21%	12,12%	3,03%	9,09%
5. Poor cost estimation	12,12%	18,18%	0%	15,15%	27,27%	21,21%	6,06%
6. Poor tendering documents	12,12%	9,09%	12,12%	6,06%	6,06%	30,30%	24,24%
7. Poor material management	3,03%	3,03%	15,15%	6,06%	15,15%	12,12%	45,45%

The second question of the survey is: How would you rate the application of automation, artificial intelligence and robotics in your environment? The most of partisipant's answer was that the applicaton of automation, artificial intelligence and robotics is poor (36,80%). The answers are shown below.

Figure 6. The application of automation, artificial intelligence and robotics in our environment

The construction industry is one of the least digitized and automated industries, the construction projects could be completed more efficiently with the use of all the benefits of Artificial Intelligence and advanced robotics, because construction projects follow many tasks and repetitive or similar activities. On the question what do they think when the application of these technologies could reach its greatest potential in our environment, the answer of survey's participants is very encouraging, almost half of participant think that these technilogies could reach its greatest potential in our enviroment in next 10 years. The survey's participants answers are shown below on figure 6.

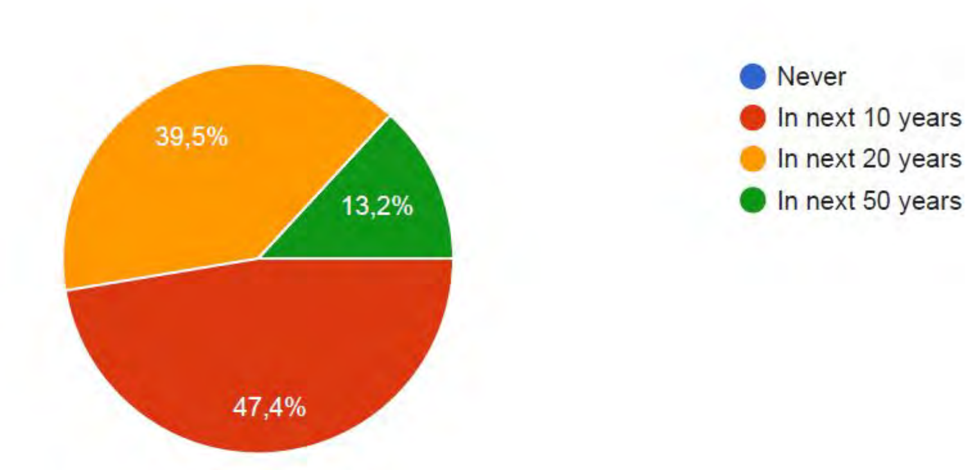

Figure 7. Automation, AI & Robotics - greatest potential in our environment

On the open question most of participants are list as the biggest shortcoming of the project lack of quality project documentation, very poor quality of project management and poor organization of construction sites. That is not only case in construction project of Healthcare facilities, is also the most common shortcomings in major project. Every major project need great project management and perfect organization of construction site. On question what do they think that by applying AI, robotics, BIM and automation in the process of redesign of Project and construction, the problems that arose could have been managed in a better way, only 5.3% of participants believe that these shortcomings cannot be mitigated by the use of these technologies. While 47.4% of respondents think they can, the same number chose as the answer - maybe. The answers of the participants are shown in Figure 8. The biggest problem with the application of advanced technologies in construction is distrust of the modernization and application of advanced technologies.

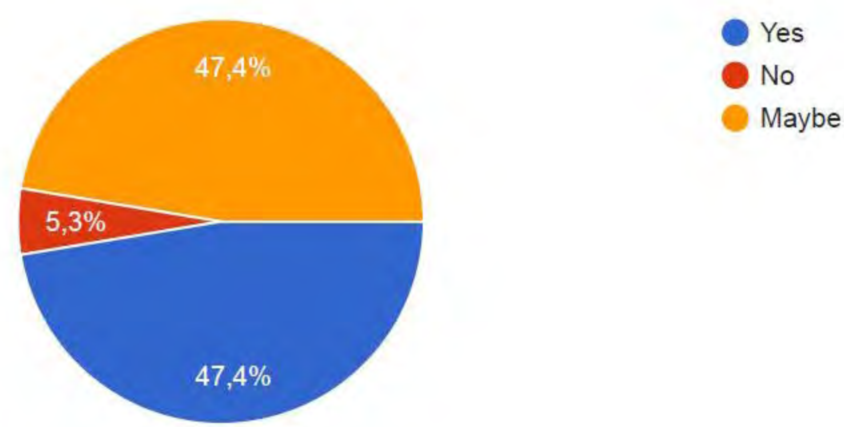

Figure 8. AI, robotics, BIM and automation –managing and solve the problems of construction project.

3. Conclusion

Construction industry is experiencing a concerning labor shortage. This labor shortage is negatively affecting the productivity in the construction sector. Unfortunately, the benefits of robotics are not yet fully realized due to its slow adoption by the construction sector. Some limiting factors of the slow adoption rate of robotics in construction include high implementation cost, fragmented nature of the industry, incompatibility with current workflows, immaturity of construction robotic technology, among others (Delgado 2019). From adopting better planning methods, to creating a culture of transparency and better collaboration among clients and workers alike, through the implementation of technology, there are plenty of methods and tools that can help identify potential risks and mediate them early in the process. Using of AI and Advanced robotics can be prevent many potential risks or at least reduce them. Every construction project lies on the foundations, the foundation of every project is project management, if the project management is bad, the whole project will have many of irregularities and shortcomings. The capabilities, tools and techniques offered and provided by AI and Advanced robotics greatly facilitate project management and brings the errors to a minimum. It is very important, that the engineers in our environment believe that the application of advanced technologies can help manage construction projects, and this is the first and important step in the implementation of these technologies. Accepting change is an important and first step in any kind of progress.

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AI in Construction Planning and Scheduling: Status of Achieving the Promise

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Abstract:

Artificial intelligence (AI) in the AEC industry is not unknown, although the market is too small for companies' commercial viability. In recent years, AI in construction planning and scheduling projects is becoming increasingly popular (at least in Academia). Using AI can reduce construction time by about 40%, reduce project costs by about 30%, reduce construction defects by about 20%, and improve project quality by about 20%. Planning and schedule have the most significant impact on developing projects related to other project lifecycle phases and contain the biggest challenges in achieving project and project management success. Meeting the requirements and deadlines is the responsibility of the project management role and has a basis in planning and scheduling. AI techniques are increasingly applied to identify problem areas where the existing approach needs quick improvements. It is a combination of computer science and operations research. Nevertheless, AI in construction planning and scheduling is a promising concept in today's demanding and complex environments. The ability of AI to use collected knowledge and lessons learned to perform tasks usually performed by humans can facilitate planning and provide gains for project success. Based on the literature review, this paper answers the question of whether AI is achieving the promise as it was expected so far. The status of achieving the benefits from it and the lessons learned are shortly discussed.

Keywords: *AI in planning, scheduling, artificial intelligence in construction project planning*

1. Introduction

Firstly, the construction industry accounts for 6% of the global GDP. Compared with 2018, the construction output reached 85% more revenues than in 2014 (AD, 2018). Generally, the construction industry is known as a poorly productive industry. A better understanding of relations in the construction industry can be the driving force for improving its productivity and influencing the comprehensive development of a country or beyond. Secondly, planning is the project lifecycle phase in which efficient interventions and actions are more than possible. It is the most crucial phase for achieving project success. No other phase will ever leave such an impact or facilitate the success of projects as project planning will. Thirdly, AI is a relatively new technology for the construction industry. In the current conditions in the construction industry, practitioners expect a lot from AI, as many previous concepts seem not to work.

Connecting planning in the construction industry and AI is complex in many aspects. Initial skepticism already arises about the scale of AI applications. The practicality of the data already collected and available in the projects and its credibility is questionable. Next, there is the legitimate question of the necessary input data. There is no purpose in considering input data without knowing specific tools that will be applied and vice versa. It is hard to clarify what is first - choosing AI methods and tools or defining input data. Classic project analysis beyond AI dictates input data selection first, and the tools defining is afterward. In AI, it goes simultaneously.

AI in planning construction projects includes scheduling and cost processes. In other words, it facilitates sequencing activities, estimating resources, and durations of tasks and activities. AI also supports schedule development and control, cost estimation, and performance control. Resource estimation consists of developing and managing teams throughout the project life cycle. It is directly related to managing communications, performing risk analysis, planning risk responses, conducting and controlling procurement, and managing stakeholder engagement.

The numbers are relentless. There is no doubt that there is considerable potential for the further use of information in construction project planning, even if the data collection method is not changed or added. Technology, especially communication technology, has become one of the most impactful factors for developing companies and projects. 96% of the data captured goes unused in the construction industry, while construction teams spend 13% of working hours looking for project data and information (Snyder et al., 2018). Alzara et al. reported delays in 50% to 150% of tall building projects (Alzara et al., 2016). Other authors suggested that only one-eighth of building contracts completed their projects within the scheduled completion dates and that the average time overrun exceeded 40% (Bromilow, 1969). Regarding integration, 30% of AEC companies use applications that do not integrate (Snyder et al., 2018). This incompatibility creates confusion and consumes time primarily unaccounted for in project planning.

AI possesses the perception as a theoretical field, with doubt about its impact on practice, but still a very ambitious field. Since AI is an innovative and complex field, few people have the basic knowledge or the skills to deal with it in their daily jobs. AI will develop market-ready solutions for many managers. It is further amplified when it comes to the implementation phase. There is a requirement for a group of people who not only know but agree to commit time to implement AI and manage the change process involving different teams and departments.

2. (At least) The need is recognized

A few main focuses for delivering successful products include schedules and resource distribution plans. Companies have failed in new product development because of difficulties in constructing reasonable development schedules and resource distribution plans (Park et al., 2011). There is a need for developing an intelligent system with respective databases of previous product development projects to estimate the duration of project phases and facilitate scheduling quality improvement.

Some authors show the dire state of the growing number of incomplete tall buildings (CTBUH, 2014). CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) are the most recognized planning methods in construction, but those traditional approaches assumed deterministic activity durations - which is unrealistic to expect in the uncertain and changing environment. (Zammori et al., 2009). AI can respond to the dynamic project environment, but the transition to AI technology is not smooth in construction practice. First, AI requires standardization and digitalization. It is the root cause of why developed regions are better motivated to apply AI than others.

The cultural and economic component of standardization forms the foundations and determines AI technologies' time, motivation, and interpretation. Taking advantage of these technologies depends on the degree of previous standardization and digitization. Digitization determines relationships between the duration of project phases and other data stored in an enterprise's information system. Any comparative analysis using AI must consider these settings. In the same way, the AI results interpreted in project planning and the recommendations based on AI predictions require competent experts and a serious approach. Otherwise, the application of AI recommendations can have opposite and unwanted consequences in non-standardized conditions.

Developed environments with an efficient enterprise resource planning (ERP) system database contain an excellent preparation for AI, including many attributes to monitor. They are potential variables for identifying the duration of refined products. In such systems, introducing and realizing AI advantages is easy and fast. In the opposite case, the basis for establishing an AI is more complex and questionable – whether to establish ERP or AI first, as the benefits of ERP are long-term and always with effective positive contribution. Fuzzy logic and artificial neural networks are complementary technologies and powerful design techniques that can identify patterns within an extensive database and noisy data (Relich and Muszynski, 2014).

There is no definitive answer to the question of the types of projects for which the application of AI is suitable. AI is not limited to one type of project. Infrastructure projects were pioneers here, which is expected due to their nature and general importance. At the same time, residential construction responds to an impending housing crisis and urban population explosion. A serious approach to the observed significant time and cost overruns in these projects will result in a comprehensive positive impact on the development of entire urban units and intelligent cities, without which there is no future today.

As with statistical calculations, the rule "garbage in - garbage out" applies here. The datasets given to the system for learning are either a guarantee of reliability or the general cause of the AI system's unsuitability. Compared to the traditional approach, AI goes beyond simple logic, which is the most valuable strength of AI. The more complex and unfathomable projects are by standard planning methods, the greater the likelihood that AI will help understand these complexities. The state of the project is more ready for the application of AI, as there are numerous and credible data on similar projects, according to which the advanced AI system can learn to offer meaningful and applicable conclusions.

3. State-of-the-art

Dataset is the key and first element for AI implementation in construction projects. Formal gathering and mining of construction projects' data can create practical corporate value and facilitate evidence-based decisions (Mohamed and Moselphi, 2022).

Cost estimation is more represented in Machine Learning systems than duration estimations. Cao et al. (2018) utilized an ensemble of Machine Learning models to estimate the cost of 1,400 unit-price resurfacing highway projects, and their Mean Absolute Percentage Error (MAPE) was 7.56%. Regarding the duration estimation, there have been several great

AI application studies by now, analyzed recently by scientists (see Figure 1). During research so far, researchers considered delays, inflation, price categories, and many other numbers and project characteristics. Artificial neural networks are the most applied technique in duration estimation studies.

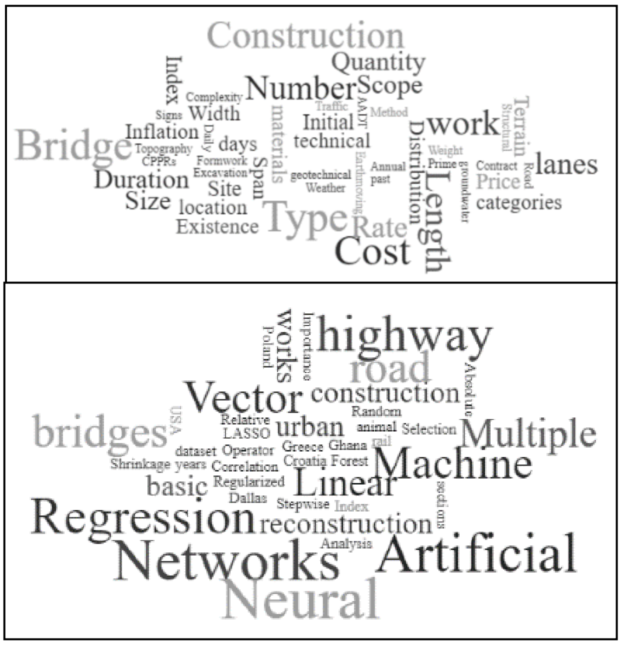

Figure 1 Parameters used and Techniques: Wordle analysis from the Conceptual Duration Estimation Studies – source: Mohamed and Moselhi, 2022

The construction industry has not fully exploited the capabilities of machine learning in making use of the abundance of historical projects' data for estimation purposes (Mohamed and Moselhi, 2022). For example, the recent AI study on highway projects shows unexpected factors that impact project duration and costs. Namely, the estimation of durations and expenses is very sensitive to the constructed facility type, the choice of payment, and procurement methods. It is a relatively new cognition presented for the first time in duration and cost estimation studies to date (Mohamed and Moselhi, 2022). According to the same research, highway projects experiencing more than 60% of delays contain associated events such as "government shutdown, utility relocation, disputes, crane productivity issues, and unpredicted condition." What is more, the reports of projects with lower delays (30%-60%) had other occurrences such as "aggressive schedule, value engineering issues, and completion incentive"; In contrast, project reports with less than 30% delays had associations such as "allowed overlap." New knowledge and categorization of the causes of delays can significantly contribute to finding the optimal solution for improvement.

Such insights can interpret past projects' experiences and improve future planning to avoid preventable setbacks in highway project execution. Experiencing the project management activities in south-eastern European countries show the same impact factors, which interfere and change the initially planned time and costs.

A literature review shows that more than 20 factors affect project activity duration (see Figure 2). Predicting models should be integrated into the construction information system to promote evidence-based decision-making, enabling constructive project risk management initiatives (Egwim et al., 2021).

Project size	Cash flow during construction
Inflation or sudden increase in commodities	Goverment regulations
Labour dispute or strikes	Material procurement
Effective or poor communication among stakeholders	Site conditions
Inclement or bad weather	Political influence
Contractor's financial difficulties	Project schedule/program of work
Structural design variations	Site accidents
Late deliveries of materials/equipments	Project quality control
Change orders/discrepancies in contract documents	Late payment
Price fluctations	Proportion of unskilled labourers
Contract management	Late delivery of materials by supplier
Decision making	Project delay

Figure 2 List of features and target for project duration prediction (Egwin et al., 2021)

Predicting model can be very useful for all stakeholders: contractors, designers, technical consultancies, local government agencies, and technical tendering authorities. In attempts to predict the duration of the activity, the scientists combined statistical methods (specifically IBM SPSS software) with the ANN method that followed selected project parameters, while WEKA for quantitative variables was additionally used (Karadimos and Anthopoulos, 2021). In the case where the dependent variable was the actual duration, the most efficient model was the one that included the following variables: Deck length, bridge surface, the quantity of deck concrete, actual cost, budgeted cost, single/twin bridge, the maximum height of piers and the piers' construction method. Furthermore, the study clarified that factors such as archaeological findings, project financing, weather conditions, environmental permits, and expropriations could cause an increase in the actual cost and the actual duration of a bridge (Karadimos and Anthopoulos, 2021).

Followed by the international conducted survey on AI application in the construction projects (Holzmann and Lechiara, 2022), there are internal and external barriers to adopting AI in construction projects (see Table 1).

Table 1 Barriers to adopting AI in construction project management (Holzmann and Lechiara, 2022)

Internal (company-related)	External (industry-wide)
• Corporate culture	• Technological aspect
• Digitization immaturity and data logistics	• Solutions in the market
• Lack of product awareness	• Legal/ethical aspect
• Financial aspect	• Country and culture
• Lack of knowledge and skills	
• Implementation effort	

The research is partly devoted to a broader perspective that considers the digital readiness of the country where the projects are taking place. These studies clearly show that the medium in which AI exists is essential for its successful application and interpretation.

An analysis of expectations for using AI technologies in different countries reveals that companies in developed economic systems with a typically high degree of digitization are in a better position and more willing to apply AI. However, they are not optimistic about the global application of AI. In less digitized environments, it is first necessary to create preconditions and concentrate on retrieving input data. In developed regions, the focus is on processing and legitimate application of existing databases on projects.

Cultural factors and the initial level of digitization are likely to influence whether companies decide to integrate artificial intelligence into project management. These companies will likely have a competitive advantage, especially in the rapidly developing international construction business (Utama et al., 2016; Holzmann and Lechiara, 2022).

AI methods tested on specific projects show different data reliability and results. Rigid, generally recognized knowledge about the preconditions for AI successful application still does not exist. Research deals with comparing AI methods in concrete cases, while comparisons are limited.

An example of resource forecasting research proposes a time series solution to the dynamic scheduling problem (Sai and Wenqi, 2021). The study valorizes two sets of databases and concludes about the reliability of the applied long-short-term memory (LSTM) recurrent neural network (RNN) model with the Gated Recurrent Unit (GRU) variant. Performance metric results show the best performance of LSTM for predicting successors and renewables. Moreover, the performance of LSTM is compared with the GRU model. The MAE of the LSTM is better than the GRU model in most cases.

4. Techniques and technical performance of AI in planning construction projects

There are several famous machine learning algorithms with their advantages and disadvantages. Mainly, advantages and disadvantages depending on the input data, system requirements, and precision of the desired results: Artificial Neural Networks (ANN), Support Vector Machine (SVM), Random Forest (RF), Ensemble Learning (EL), Multi-Linear Regression Analysis, k-Nearest Neighbors (KNN), Ensemble Methods.

Scientists set new methods and combinations of existing algorithms to obtain even more credible and applicable results (Mohamed and Moselhi, 2022; Sanni-Anibire et al., 2021). Machine learning is always an accompanying activity or step by which the input data becomes the basis for calculations of the AI system. The state-of-the-art analysis shows that ANN is the most used model, followed by regression and SVM. Mainly, it is due to the ANN's ability to provide a generalized optimal solution with high accuracy and less time.

Along with project management research, AI connects many technical, technological, and organizational parameters on projects together. In the performance evaluation of various AI models, specifically at soil shear strength prediction and pre-project cost and duration, metrics such as RMSE, correlation coefficient (R), MAPE, MAE, coefficient of determination (R2), VAF, and AAE were the most used metrics (Sharma et al., 2021). The inherent uncertainty and imprecision in project scheduling have motivated the proposal of several fuzzy set theory-based extensions of activity network scheduling techniques (Relich and Muszynski, 2014; Long and Ohsato, 2008; Maravas and Pantouvakis, 2011).

With all the listed possibilities of AI algorithms, competent experts are necessary for AI implementation and interpretation. If the method is appropriately selected, whether artificial neural networks, fuzzy neural systems, or linear regression nowadays, but the competency is missing, then there will be no achieving planned goals. The competencies remain the major input factor. One is analyses of the data, and the other is procuring those data for analysis. The competencies are different here and should be appropriately applied.

Nevertheless, data mining is AI's first consideration, regardless of the specific method used. It is much more than collecting information on projects - there is presentation, transfer, access, and use of data followed by data gathering in the data mining activity. Data mining tasks are descriptive and predictive at the same time (Han and Kamber, 2006). The relationship between ERP (Enterprise Resource Planning system), duration estimation, and data mining is significant to understanding the system, which has been covered in research so far (Relich and Muszynski, 2014).

After data mining, estimations are the second key point of AI. Estimation quality is a well-known key focus for scheduling improvements (Relich and Muszynski, 2014). Knowledge discovery in databases (KDD) has evolved into a research direction in fields such as databases, machine learning, pattern recognition, statistics, artificial intelligence, reasoning with uncertainty, expert systems, signal processing, and information retrieval (Cios et al., 2007; Han and Kamber, 2006). KDD is the process of discovering previously unknown and potentially interesting patterns in large databases. But it is not as simple as that. KDD is the nontrivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data (Relich and Muszynski, 2014). The steps of the KDD process can be generalized into four further considered subprocesses: data selection, data transformation / preprocessing, data mining, and interpretation/evaluation of patterns (Relich and Muszynski, 2014).

Here is a short description of two primary AI methodologies applied in construction planning so far:

Artificial neural networks (ANN) are an essential classification of tools for quantitative modeling. Neural networks are computing models for records processing and are mainly beneficial for figuring out the quintessential relationship among a set of variables or patterns in the data. Today, neural networks are treated as a fashionable information mining tool and used for many data mining tasks such as pattern recognition, time-collection analysis, prediction, and clustering. Several necessary traits of neural networks make them suitable and valuable for data mining. For instance, ANN does not require numerous unrealistic a priori assumptions about the underlying data-producing system. There is no need for precise model structures. It establishes the mathematical models that accurately approximate reality or represents many complex relationships in the projects. ANN is a nonlinear model. Therefore, ANN can clear up issues with imprecise patterns or records containing incomplete and noisy information with a giant quantity of variables. ANN, with their nonlinear and nonparametric nature, are extra high-quality for modeling complicated information mining problems (Zhang, 2010).

A fuzzy neural system (Fuzzy) has the advantages of neural networks and the fuzzy simultaneously, as the name says. Neural networks bring mastering abilities, optimization abilities, and connectionist structures, while fuzzy methods here mean simplicity of incorporating expert knowledge. As a result, it is possible to bring the low-level mastering and computational power of neural networks into fuzzy structures. Besides, it means high-level human-like if-then thinking and reasoning of fuzzy systems into neural networks. The fuzzy neural approach is a way to create a fuzzy model from data with the aid of some getting-to-know process inspired by gaining knowledge of tactics used in neural networks. This method significantly reduces the time for developing the model and reduces price while improving the accuracy of the resulting fuzzy model. Combining neural networks and fuzzy modeling implies the possibility of fast updating and adopting any changing parameters in projects. Updated or adapted numerical facts achieve an even higher benefit than a neural community that cannot use linguistic data and behaves as a black box (Relich and Muszynski, 2014).

Figure 3 shows the sequence of AI implementation activities to support the determination of activity duration. This flowchart does not differ regardless of the chosen AI method, and represents the backbone of the necessary input actions, tools, and results of time estimation on projects.

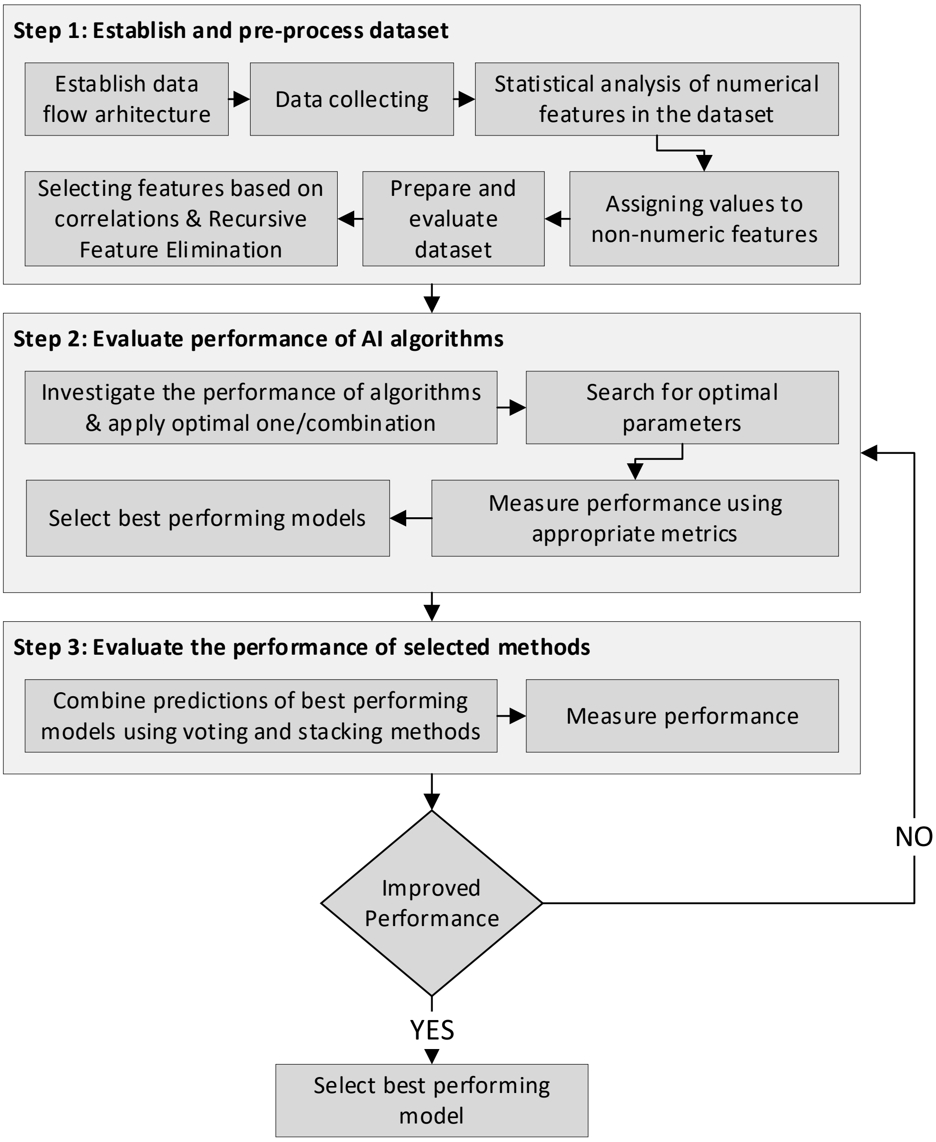

Figure 3 Steps for AI support for duration prediction (Sanni-Anibire et al., 2021, adjusted)

5. AI advantages and challenges

AI has applications in progressive organizations and systems. The scientific and professional literature analysis revealed that AI applications exist in high-rise construction and infrastructure projects (roads, etc.), which are significant in terms of costs or are substantial for the community. In other words, the overall development of the construction industry shows the amount and ambition of AI implementation - the relationship is proportional.

AI's main strength, at least for the time being at the beginning of the application, is prediction and analytics for each AEC role (architectural, engineering and construction role) through the project life cycle. Expectations in this area are the highest. The benefits from the perspective of the main stakeholders are as follows (AD, 2019):

- For executive leaders, it means viewing company-wide performance metrics across multiple projects and getting insight into projects that need executive-level interventions,
- For project leaders, gain visibility into project reports, data, and risk prediction capabilities to avoid costly mistakes.,
- Project members utilize machine learning and predictive capabilities to provide actionable to-do lists.

The advantages of using intelligence systems include searching the complex and potentially valuable relationships in an ERP database and their use in estimating project duration. The more exact identification of project duration enables more precision in project planning and scheduling, as well as improves cost planning. This approach benefits production enterprises with a database of previous product development projects.

Advantages of AI in construction planning in overall are (Abioye et al., 2021; Ghallab, 2004):

- Cost savings due to improved processes e. g. logistics,
- Increased productivity,
- Reduced planning effort,
- Simplified monitoring and control,
- Optimal plan and schedules contribution.

The results indicate better estimation quality of intelligent systems than statistical models—also, variable selection and preprocessing influence the obtained results. The experiments worldwide recognize the importance of careful parameter choice for intelligent systems, ANN's structure and learning algorithm, and the need for result comparison for different forecasting models (Relich and Muszynski, 2014).

The utility of the AI encounters some difficulties, amongst other things, with the series of adequate quantities of information from previous comparable projects. Moreover, the lack of uniform regulations for constructing the structure of neural networks and fuzzy neural systems may additionally motivate an acceptance issue for decision-makers (Relich and Muszynski, 2014).

A published case study of AI application in BellHawk Systems corporation, regarding real-time AI for scheduling and planning make-to-order manufacturing, explains that with satisfying few requirements, the AI would not be needed (BellHawk, 2016). Those requirements include everything going according to the plan and schedule, which is even hard to imagine in today's fast change project environment. There are many unknown factors than directly impact performance. Machines break down, employees fail to show up for work, operations take longer than planned, and parts may be found to be defective or need rework. AI must facilitate those uncertainties, as frequent re-planning and re-scheduling almost always consume large amounts of costly management and staff time. Many organizations try to solve these planning and scheduling problems by adding staff members, such as expediters, to ensure that products and activities arrive on time. But all that happens is that overhead costs increase dramatically. As a result, orders are shipped late, and profits plummet. In other words, in a real-time make-to-order world, there is no "optimum" schedule because the future is unknown, and the decisions can be based only on the facts available now, not considering unknowing future factors (BellHawk, 2016).

6. Conclusion

AI is a relatively new research field, especially when considering construction planning. Its applications are sporadic and individual, still being applied to a small number of projects. Generally, the applications so far are in the high-technological and digitalization environment rather than in undeveloped regions and backgrounds. Those backgrounds partly determine AI results. There is great expectation for new technologies and potential for AI in construction planning. Recognized potential and expectations are limited by the reliability of models that bring approximations as closer to uncertain reality as possible.

AI lives up to its expectations, as hesitancy prevents an ambitious view of all possibilities, especially in environments with a lower level of digitalization. On the other hand, it is already clear from existing applications and the research results that this area is more comprehensive than initially imagined. AI will undoubtedly offer previously unexpected solutions and show hitherto unknown parameter relations in projects. Those relations and connections will supplement the theory of project planning and thus significantly improve the practice of possible delay risk predicting. Therefore, more effort and research should be directed towards retrieving relevant data, and AI will take care of the results - even better and more efficiently than humans can predict. Until the level of digitization of the profession is equalized, more digitally developed areas will have better results and more use of AI in construction planning. In less digitally ready environments, it is necessary to focus on standardization and digitalization to acquire the prerequisites for fully exploiting the potential of applying AI in construction planning.

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Investigation of the Learning Curve Effect on the Construction of Wind Turbine Erection Projects

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Abstract:

This paper investigates the learning curve effect on construction productivity for the erection of wind turbines. The research exploits the extent to which the learning phenomenon improves a construction process that is characterized by an iterative and repetitive nature. The research significance is enhanced since it contributes to the rather unexplored body of knowledge about the learning phenomenon effect for renewable energy projects. Two learning curve models have been selected for the analysis, namely the exponential and Stanford B. Both unit data as well as cumulative average data have been used stemming from a series of field observations. The dataset has been divided in two sub groups, each one representing the two deployed crews for the execution of the activities. The first group was inexperienced while the second had prior experience in similar activities. The results denoted that the learning phenomenon is more intense (lower learning rate) in the exponential model rather than the Stanford B model, while the inexperienced crew demonstrated a better learning performance. The research can be expanded in order to include both more field data as well as more learning curve models so as to provide a holistic notion of the construction management procedure.

Keywords: *construction productivity; estimation; learning curves; renewables; statistical analysis*

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1. Introduction

Construction productivity is estimated by taking into account a series of different factors involved in the execution of the project. One of the main productivity drivers is the repetitive nature of specific construction activities. The observed construction productivity improvement comes very often as a result of the learning phenomenon, which is developed amongst the deployed crews. As such, productivity in repetitive construction activities is increased along with the experience and familiarization of the crews with the project scope. This research investigates the effect of the learning phenomenon in a large-scale wind turbine project with a particular focus on the erection activities. A comparative analysis is conducted between two largely applied and accepted learning curve models (Stanford “B” and Exponential), which to the authors’ best knowledge represents the first research attempt to apply such models for wind turbine erection projects.

The latter represents one of the most common renewable energy projects’ type, as well as a characteristic example of sustainable green project management. Due to the increasing interest in renewable energy projects, it is very important to investigate ways of improving project programming in relation to the labour-intensive resources. More specifically, in the case of wind turbine projects, the erection activities are usually executed under adverse weather conditions, which generate delays and downtime in the involved equipment / crews.

Therefore, it is very important, even at the design stage, to be able to specify these activities' duration in the most efficient manner, in an attempt to minimize uncertainty. The learning effect has not been incorporated in day-to-day operations of wind turbine erection projects, thus creating a research gap, which -if covered- may generate a significant cost and time improvement margin.

In that respect, the main research problem relates to the expected on-site productivity of wind turbine erection crews. From a managerial point of view, the development of the learning phenomenon is very important for two reasons: first, if the learning rate is intense, then the erection process is going to be significantly accelerated and given the repetitive nature of the works, the ultimate cost saving effect is notable. Secondly, at the beginning of a construction activity, especially if it is labour-intensive such as the wind turbine erection process, the demonstrated progress might be slow. However, if the project manager decides to increase the deployed project resources as a mitigation measure to the slow progress rate and then the learning phenomenon is developed, the project could end up being over-resourced at a maximum productivity plateau with increased daily costs in relation to the estimated cost at the design stage. In other words, the incorporation of the learning phenomenon in the decision-making process reflects the dynamic nature of project planning and aids the project manager in reaching informed decisions. Within this framework, the main research question may be formulated as follows: "Which learning curve model reflects more effectively the on-site wind turbine erection productivity in relation to deployed crews with different levels of prior experience?". The parameter of previous experience in the deployed crews affects the "starting point" of their productivity rates, since -in theory- an inexperienced crew will demonstrate initially a lower productivity rate (hence, bigger margin for improvement) in comparison to an experienced crew. The anticipated response to the research questions will designate the course of action in terms of resource planning and project scheduling. Therefore, the research findings are targeted at providing critical productivity data to the Project Management Office of the organization, so as to (a) fine-tune the construction process in running projects and (b) create a historical database of productivity data that will improve the estimation process in future projects.

The structure of the paper can be broadly described as follows: First, background information on published research for the learning curve theory as well the respective models is provided, followed by a concise description of the wind turbine erection process. Then, the research methodology is presented and, subsequently, the fitting results for the selected models graphically illustrated. Finally, the main inferences emerging from the study are described together with the formulation of proposals for research expansions directions.

2. Background

2.1. Learning Curves

2.1.1. Theoretical Concepts

In the event that a series of "sufficiently complex" activities is executed, the learning curves are utilized to represent in a graphical manner the time span, the cost and/or the labour hours which are necessary for their execution (Everett and Farghal 1994; Ralli et al. 2020). The learning curve theory suggests that the required time (labour hours) for the production of a single unit (e.g. erected wind turbine) is incrementally decreasing as a percentage of the time that was demanded for the production of the previous unit (UN 1965). This percentage is called "learning rate" and is a characteristic variable for the extent of the learning phenomenon in a single construction activity (Thomas et al. 1986). The learning rate, if interpreted mathematically, coincides with the inclination of the learning curve. The learning phenomenon becomes more intense for smaller values of the learning rate. The latter is explained by the fact that each subsequent production cycle is a smaller percentage of the time required for the previous production cycle. For example, a learning rate of 70% denotes that every subsequent unit is going to be produced at a time period of 70% less, than the production time of the previous unit. If no learning effect is present in an activity, then the learning rate is equal to 100%.

The learning curve theory may be used either to describe the production time of a single unit or the cumulative average time to complete a number of units (Panas and Pantouvakis, 2014). The former case regards the so-called “unit data” while the latter case relates to the “cumulative data”. The cumulative data are computed by taking the total time required to install or construct a given number of units divided by the number of units completed (Panas and Pantouvakis, 2018). The research adopts both data types, in order to provide a holistic analytical framework. The analysis has been based on the statistical approach for the elaboration of the learning curves from the provided field data (Thomas et al. 1986; Srour et al. 2016).

2.1.2. Learning Curve Models

The learning curve phenomenon is studied through the use of specific mathematical models, which interpret the variation of productivity in relation to critical factors such as the number of units (Everett and Farghal 1994; Thomas et al. 1986). This research uses the following two learning curve models (Ralli et al., 2020):

1. **Stanford "B" Model:** It was developed, by the Stanford Research Institute in 1940’s. This model is considered a modified Straight-line model which includes a factor "B" to represent the number of units of prior experience and shifts the learning curve downward (Srour et al., 2016). It assumes that the Straight-line model is the normal situation provided the crew has no experience resulting from performing similar activities or constructing similar units in the immediate past. The value of B fluctuates within the range of 0–10 (Mályusz and Pém, 2014). A crew with no prior experience will have a value B equal with zero, while an experienced crew may have an experience factor of four or higher (Thomas et al. 1986).
2. **Exponential Model:** It was developed by the Norwegian Building Research Institute in 1960 (U.N. 1965). It is based upon the rule that part of time/cost per unit is fixed and the other part of time/cost per unit, which can be reduced by repetition, will be reduced by one-half after a constant number of repetitions (Zahran et al. 2016). The ultimate or lowest cost or man-hours or time per unit at the end of the routine-acquiring phase (Yult) must be known along with constant "H" which represents a "Halving Factor", namely the number of units required for that part of the unit cost which can be reduced by repetition to one-half. A learning curve model for cumulative data was not presented (Thomas et al. 1986).

The mathematical expressions for the estimation of productivity based on the aforementioned learning curve models (LC models) are summarized in Table 1 and their graphical representation is depicted in Figure 1 below:

Table 1. Mathematical Expressions for Learning Curve Models

LC Model	Mathematical Expression
Stanford "B"	$Y = A\cdot(X+B)^{-n}$ or $\log Y = \log A - n\cdot\log(X+B)$
Exponential	$Y_u = Y_{ult} + (A - Y_{ult})/(2\cdot X/H)$
Where (in order of appearance):	Y=unit or cumulative average cost, man-hours or time; A=cost or man-hours or time of first unit; X=unit number; n=slope of logarithmic curve; B=factor describing the crew's prior experience; b=initial logarithmic slope at the first unit; C=quadratic factor; D=cubic factor; Y_{ult}=ultimate man-hours per unit at the end of routine-acquiring phase; H=constant named "Halving Factor".

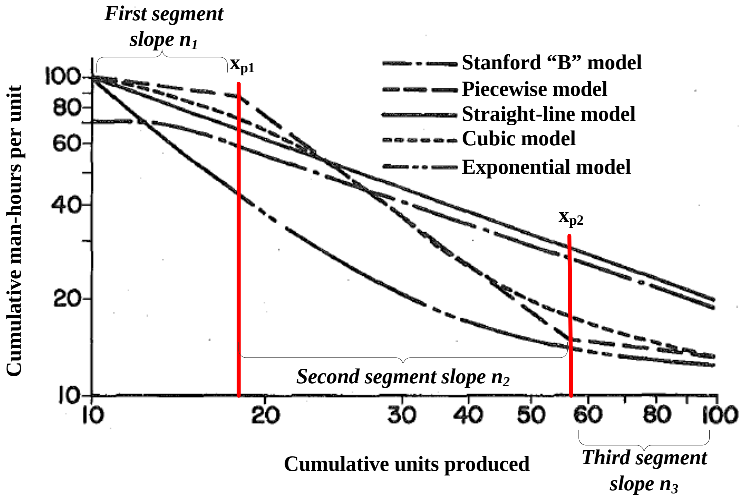

Figure 1: Shape of Various Learning Curve Models (adopted from Thomas et al. 1986)

2.2. Wind Turbine Erection Operations

The upper structure of a wind turbine is primarily comprised of metal parts that constitute its tower, the nacelle that sits on the top and contains most of the electromechanical equipment (e.g. gearbox, brake), the hub, the generator and the rotor blades. As far as the erection process sequence, the erection of a wind turbine with such geometrical characteristics starts with a topographic surveying for the positioning of the tower's first segment on its foundation (with an accepted deviation of +/- 1.5mm). Subsequently, high quality concrete (>80MPa) is poured in order to stabilize the tower to the foundation. Cubic tests are undertaken within 48-72 hours in order to verify the concrete's strength and capacity. Due to that requirement, a specialized crew takes over the aforementioned process, while another team assembles the electromechanical equipment which is positioned at the tower's base (transformer), followed by the four (4) metallic tower segments. Upon the completion of the tower's erection, the erection of the nacelle follows along with its electromechanical equipment, followed by the installation of the generator. Then, the rotor blades are positioned in the hub on the ground and then they are erected as a group. If the rotor blades are too long and the erection site is of limited space, then the hub is first erected alone and then each rotor blade is positioned separately on the hub. When all the aforementioned erection activities are completed, the final erection activities are executed (silicon installation, cleaning etc.). The list of the requested tasks to complete the wind turbine erection activity is summarized in Table 2 below.

Table 2: Requested tasks for the execution of the wind turbine erection activity

No.	Task
1	Topographic surveying of the lowest part of the wind turbine
2	High-strength concrete pouring on the wind turbine base
3	Installation of electromechanical equipment on the wind turbine lower part
4	Erection of 2^{nd} wind turbine segment
5	Erection of 3^{rd} wind turbine segment
6	Erection of 4^{th} wind turbine segment
7	Erection of 5^{th} wind turbine segment
8	Nacelle erection
9	Generator erection
10	Installation of 1^{st} rotor blade in the hub on the ground
11	Installation of 2^{nd} rotor blade in the hub on the ground
12	Installation of 3^{rd} rotor blade in the hub on the ground
13	Hub and rotor blades erection
14	Close-out works

3. Research Methodology

The wind turbine erection activity was studied within the framework of a large-scale wind energy project in Central Greece. The project comprised the erection of thirty five (35) wind turbines with a steel tower of 78m height, thus representing one of the biggest wind turbine projects in Greece. The total project duration was twenty four months (May 2018 – May 2020), while the total erection duration of the thirty five wind turbines was twelve months (April 2019 – April 2020). In relation to the research question posed in the first paragraph, the methodology opts to provide respective answers based on the learning rate, as the most representative productivity metric. From a statistical point of view, the two learning curve models are evaluated based on their convergence to actual on-site productivity data. The following paragraphs analytically describe the steps which were followed in applying the research methodology for the specific project case study.

3.1. Data collection methodology

The construction activities were monitored during the construction period via direct supervision as well as on the basis of daily meetings with the erections contractors' representatives. The field data were collected by completing analytical daily site reports which summarized the project's progress.

Figure 2: Wind turbine erection process

It should be noted that the project characteristics satisfy the theoretical assumptions for the development of the learning phenomenon, since it constitutes a repetitive, complex construction activity. In addition, the field data represent the on-site productivity of two different erection crews, with a different level of experience, so as to associate the extent of the developed learning phenomenon to the crew's expertise.

3.2. Specification of project activities

This research includes only labour-intensive activities. In those activities the human factor is the main productive resource and the productivity is expressed in workhours per erected wind turbine. The effect of the deployed equipment -mainly the utilized cranes- in the productive erection process is not taken into account, since the complexity of that specific task is low and the participation of the human factor is limited to the cranes' operators, thus not contributing in the development of a learning curve. The total production cycle for the erection of a wind turbine includes the fourteen activities presented in the previous section and summarized in Table 1.

3.3. Selection of learning curve models

From the available learning curve models, two models were selected for this research: the Stanford "B" and the Exponential model, whose mathematical expressions are illustrated in Table 1. The Stanford "B" model was selected due to its suitability for complex construction activities, since the erection of wind turbines represents a very complex set of tasks and its ability to model the crews' experience as well. On the other hand, the Exponential model was selected due to the availability of a large set of field data which is a prerequisite for its robust response.

4. Results

The two learning curve models were investigated through the use of statistical analysis. Each model was evaluated by adjusting historical productivity data of completed construction activities and specifying which model presents the best convergence of the theoretical results with the real site data. Two types of data were used: unit data and cumulative average data. The decision to use both type is justified by the fact that cumulative average data are best suited for long-term planning, while unit data are more suitable for short-term planning. Thus, by using both types of data, a more complete analysis is offered for the construction operatives to reach informed decisions.

4.1. Learning curve data depiction

The site data are summarized in Table 3 below. As explained before, the research adopts both unit data as well as cumulative average data. The first crew (with no prior experience) was involved in the erection of seventeen wind turbines, while the second crew (with prior experience) executed the erection of eighteen wind turbines. The data were inserted in the learning models, as will be analytically described in the next paragraph.

4.2. Selection of learning curve models

All project data were plotted in an Excel spreadsheet and the learning rates were determined by applying the Solver suite. The analysis results are depicted in Figure 3 and Figure 4 for the Stanford "B" and the Exponential models respectively. Each Figure depicts the results for (a) the unit data, (b) the cumulative average data and (c) the theoretical model results for both crews. In the case of the 1st crew (with no prior experience), the first wind turbine was erected in 556 workhours, while it improved its performance by reaching 336 workhours for the erection of the 17th wind turbine. On the other hand, the 2nd crew (with prior experience) started from a significantly lower point by spending 356 workhours in the first wind turbine and completing the 18th wind turbine in 255 workhours. It is very impressive that the inexperienced crew needed ~60% more time to complete the erection of the first turbine than the experienced crew, thus designating that both crews has fundamentally different starting points in their productivity estimates. It reached the initial performance of the experienced crew at the completion of their scope.

As far as the learning rates are concerned, the Stanford "B" model yielded a learning rate of 0.9295 for the 1st crew and 0.9781 for the 2nd crew respectively. In a similar fashion, the learning rate for the 1st crew in the Exponential model was 0.9148, while the respective value for the 2nd crew reached 0.9652. From a visual point of view, it must be noted that the inexperienced crew graph (Figure 3) presents a smoother convergence in relation to the experienced crew results (Figure 4). This has to be attributed to the fact that there was a steep improvement in productivity for the last four erected wind turbines in the deployment of the 2nd crew. It is a very interesting finding because, normally, as the production of units advances (in our case the erection of wind turbines), a learning threshold is reached in the sense that the productivity improvement potential reached a plateau and no further improvement is observed. This finding may be explained by the fact that the crew had to familiarize with the steep terrain and adverse weather conditions prevailing in the construction site area and, once they achieved this familiarization, then the productivity improvement increased. On any case, the produced trend lines represent an approximation of reality and their estimating value is harnessed when the models are fed with increased number of field data that constitute the project historical data base. However, this case study has practically demonstrated that the learning curve models can graphically highlight critical productivity parameters that essentially affect the scheduling and cost management of construction projects.

Table 3: Site data per deployed crew in two formats: (a) unit data; (b) cumulative average data

1st Crew (no prior experience)			2nd Crew (with prior experience)		
Wind Turbine No.	Unit data (workhours)	Cumulative average data (workhours)	Wind Turbine No.	Unit data (workhours)	Cumulative average data (workhours)
1	556	556.00	1	356	356.00
2	486	521.00	2	340	348.00
3	497	513.00	3	342	346.00
4	491	507.50	4	342	345.00
5	452	496.40	5	334	342.80
6	461	490.50	6	338	342.00
7	420	480.43	7	316	338.29
8	443	475.75	8	318	335.75
9	417	469.22	9	323	334.33
10	418	464.10	10	315	332.40
11	395	457.82	11	309	330.27
12	386	451.83	12	307	328.33
13	380	446.31	13	304	326.46
14	377	441.36	14	306	325.00

15	363	436.13	15	287	322.47
16	355	431.06	16	292	320.56
17	336	425.47	17	255	316.71
			18	255	313.28

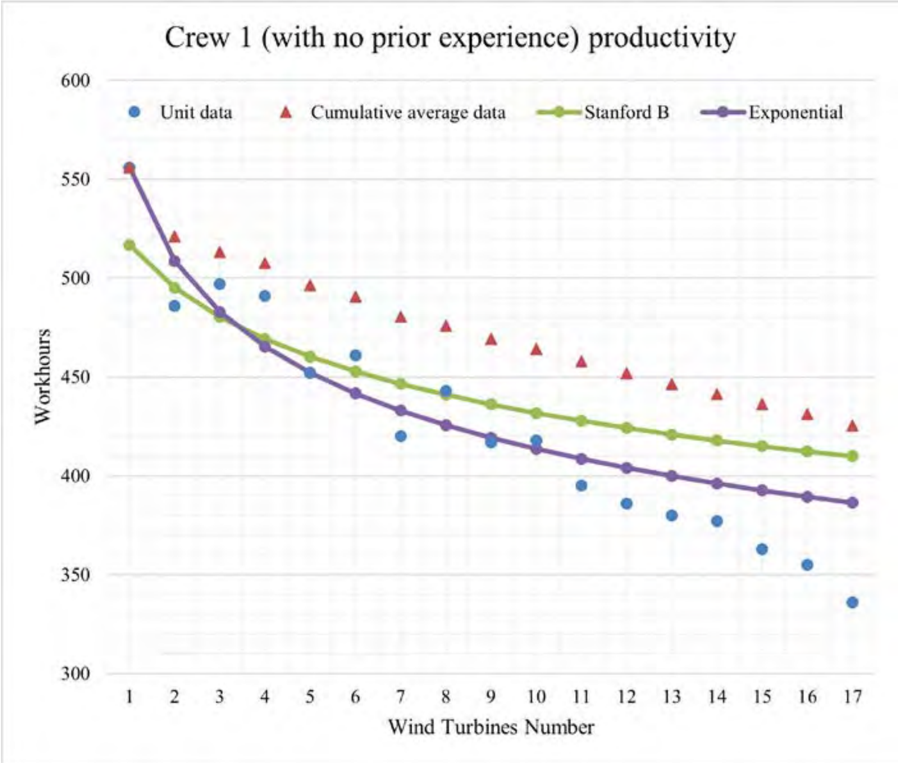

Figure 3: Wind turbine erection process

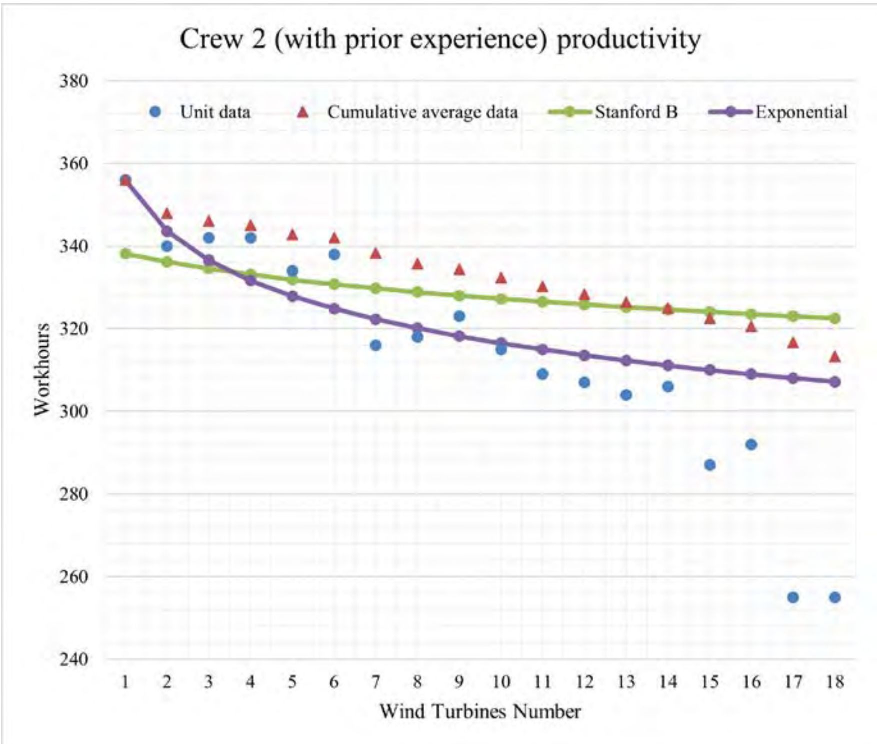

Figure 4: Wind turbine erection process

5. Conclusions

The research has shed light on a very important issue which relates to the significance of the learning phenomenon in complex construction activities of renewable energy projects. The research contribution is even more important in view of the fact that published literature on learning curve models' application in wind turbine erection projects is scarce if not non-existent.

The case study has illustrated that the erection process of thirty-five wind turbines was significantly affected by the learning phenomenon, despite the fact that erection procedure is a typical checklist-based construction activity. As corroborated in theory, the unexperienced crew generated a more intense learning phenomenon than the other crew which has prior experience in that type of tasks. Their difference in productivity lies in the range of 10% according to the Stanford B model. The inexperienced crew has similar convergence results with both learning curve models (Exponential / Stanford B) and a broad dispersion in the field productivity data. On the other hand, the experienced crew showed a better fit for the exponential model. In a similar fashion, the learning rate of the inexperienced crew is bigger than the respective learning rate of the second crew. In absolute terms, the learning phenomenon is more intense (lower learning rate) in the exponential model rather than the Stanford B model – however their values are relatively close.

The research contributes to the body of knowledge from both an academic and professional perspective. The academic value of the research lies in the fact that the yielded results corroborate the established perception that the Exponential and the Stanford B models present a very good fit for construction productivity models, even in the case of wind turbine erection projects which have not been sufficiently investigated as stated above. In addition, the managerial and professional aspect of the research lies in the fact that a low progress rate at the beginning of a construction activity should not lead directly to mitigation measures related to the increase of the deployed workforce and/or resources in general. It has been evidently proven that in the case of the inexperienced crew the initial productivity rate was significantly improved along the way. It is also noteworthy that the productivity improvement trend per se is smoother in the case of the inexperienced crew, while in the other case it seems that towards the end of the activity the performance of the specific work team improves rapidly. In that sense, the project manager as well as the estimator of future similar activities should take into account the dynamic and somewhat non-linear behavior of the human-related resources which must be numerically incorporated in the estimation models in advance. This is the only practical way to reach managerial effectiveness even under circumstances that do not favor the systematic and seamless execution of works, such as the wind turbine erection.

For clarity reasons, it should be noted that a significant project parameter has been left outside of the analysis and that is the weather conditions. In general, weather conditions vary significantly, since the activity spans over a long period of time. Wind turbine erection is very sensitive to adverse weather conditions, such as strong winds or low visibility and there are very strict protocols in place that result in works interruption in case certain operational limits are violated. However, the field data referred to working days where the weather conditions were favorable and a full working day was concluded without any problems. Besides, no work would start in case there was a strong possibility for interruption during the course of the day, because the mobilization and operational costs for a half-day operation far exceed the respective costs of rescheduling the specific operation for another day.

As a closing remark, a valuable database of combined productivity data and learning rate metrics has been created which is expandable and, thus, may constitute a benchmark against which future wind turbine erection projects may be scheduled. Especially in Europe, where the green agenda has been set at the forefront of the next decade, it is very important to support the construction operatives with reliable productivity estimates that are realistically depicting the actual construction process. It is even more important for Greece per se since such activities are particularly complex due to the steep terrain and the adverse weather conditions (high wind capacity) that prevail in the Greek region. The research can be expanded, in order to include both more field data, as well as more learning curve models, so as to provide a holistic notion of the construction management procedure.

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Integration of UN SDGs in Energy Sector Projects: A Case Study of Smart Grid Pilot Project

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Abstract:

Sustainable Development Goals (SDGs) is a framework for sustainable development policy adopted by UN member states, with a total of 17 goals with 167 targets to be achieved by 2030. The SDGs have become an integral part of the Green Deal, a key document of the European Commission. Projects which are carriers of social change will play a significant role in achieving the goals of the Green Deal. Projects in the energy sector, specifically the electricity distribution sector, will play a vital role in achieving climate neutrality. This paper aims to assess how project teams perceive the integration of different UNSDGs in electricity distribution sector projects. The research is based on a case study on a Smart Grid Pilot Project., implemented by HEP ODS d.o.o. in Croatia, including a survey and a structured interview with project team members. After the data collection, descriptive statistical and bivariate analyses were carried out. Descriptive analysis will provide an average perception score, and bivariate analysis will measure perception among different groups of respondents. The findings show that only a few UNSDGs are integrated into electricity distribution projects, prioritizing the goal that is thematically connected to the energy sector (SDG7). Lastly, the results suggest that more effort is needed to move from greenwashing to SDG-achieving. The results of this research can be helpful to project managers in improving the quality of projects and assuring the long-term sustainability of project results. Furthermore, it enables researchers to develop new models for measuring sustainability in all project lifecycle phases.

Keywords: *project management; sustainability; qualitative analysis; UN sustainable development goals; smart grid*

1. Introduction

1.1. Sustainable development goals and indicators

At the UN in New York the Open Working Group created by the UN General Assembly proposed a set of global Sustainable Development Goals (SDGs) which comprises 17 goals and 169 targets. Further to that, a preliminary set of 330 indicators was introduced in March 2015. Many international organizations implemented SDGs in their policies and strategic framework. Most of them are part of a UN partnership platform, a global registry of voluntary commitments and multi-stakeholder partnerships made by stakeholders in support of the implementation of the Sustainable Development Goals (SDGs).

Sustainable development is a core principle of the Treaty on the European Union and a priority objective for the Union's internal and external policies. It is also an integral part of the Green Deal. Green Deal is a new growth strategy that aims to transform the EU into a fair and prosperous society with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use. (European Commission, 2019). The EU was instrumental in shaping the global 2030 Agenda, which has become the world's blueprint for sustainable global development. (European Commission, 2020).

The concept of sustainable development is an attempt to combine environmental issues with socio-economic issues (Delli Paoli, Addeo, 2019). Each of the 17 sustainable development goals is focused on one area for achieving sustainability. Individual activities can contribute to more than one SDG. Thus, one activity will rarely contribute to one SDG. More often, it will affect more SDGs with different intensities and impacts. For example, there is much more research on the relationship between energy and issues such as food and water. Links from energy extend much further than this, including the SDGs on health, education, gender, economic growth, industry, cities and climate (Taylor, P. Abdalla, K. Quadrelli, R. Vera, 2017).

The European Union emphasizes actions aimed at achieving all sustainable development goals. Therefore, they were included in the policy and vision of the European Union until 2030 (Rybak, A. Rybak A. Kolev, 2021.) 2030 Agenda’s targets are structured around five critical sustainable development pillars: people, planet, prosperity, peace, and partnership—commonly known as the five Ps. In order to move toward more sustainable patterns of duction and consumption patterns, it is necessary to assess the progress in energy-related indicators (Chovancova, J. Vavrek, R. (2021).

Besides interdependencies between SDGs, there is also a wide variety of composite indicators that have been suggested to combine different sustainable development goals. SDG 7 has 6 indicators, measuring access to affordable, reliable, sustainable and modern energy for all.

Indicators are:

- 7.1.1 Proportion of population with access to electricity
- 7.1.2 Proportion of population with primary reliance on clean fuels and technology
- 7.2.1 Renewable energy share in the total final energy consumption
- 7.3.1 Energy intensity measured in terms of primary energy and GDP
- 7.a.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
- 7.b.1 Installed renewable energy-generating capacity in developing countries (in watts per capita)

A critical review has revealed that indicators of varied quality (in terms of the fulfillment of certain criteria) have been proposed to assess sustainable development. (Hák, T. Janoušková, S. Moldan, B., 2016).

The importance of projects in achieving SDGs is practical and concrete. Projects make positive progress in socio-economic development, change infrastructure, and contribute to strengthening human capacities, human rights, research and development, and food production. In fact, in each area covered by the UN Sustainable Development Goals, projects have a substantive role in bringing positive change. The process could be also observed in reverse. For projects to succeed, it is not enough just to achieve the goal in a given time and with limited resources. One of the success factors of the project is the integration of the principles of sustainability in all phases of the project life cycle.

The project management profession is moving beyond its traditional focus on time, cost, and scope to emphasize delivering the business case's objectives while maintaining an asset lifecycle focus. The next step in the evolutionary process is to adopt a sustainability ethos where projects do not come at the expense of the planet and its limited resources (Carboni, J. Duncan, W. Gonzalez, M. Milsom, P. Young, M. 2018). The project excellence model considers the importance of the identification and consideration of relevant project environments in the formulation of the project objectives and advocates the internalization of social interests in the project (Gareis, R. Huemann, M. Martinuzzi, A. (2010).

1.2. Smart grid pilot project case study

HEP – Distribution System Operator d.o.o., implements the "Smart Grid Pilot Project", which refers to modernising part of the electricity distribution network in Croatia. The project invests in three functional areas of the advanced electricity distribution network: advanced metering infrastructure, development and optimisation of the conventional grid and automation of the medium voltage grid. Advanced metering infrastructure will enable more accurate calculation of losses and locating areas with increased losses in the distribution network, monitoring electricity consumption and active management of consumption at the level of end-users. For this purpose, summary meters will be installed in 6,125 transformer stations, and 24,000 existing meters will be replaced by advanced meters at end customers. The existing 449 transformers will be replaced with new, more energy-efficient ones, which will reduce technical losses. 670 remote-controlled devices will be installed in the network's depth, which will increase the power supply's reliability and create the preconditions for the integration of distributed sources. The project covers the medium voltage network and users of the electricity distribution network in five (out of 21) distribution areas of HEP ODS.

The project implementation team includes over 30 HEP ODS employees with a support team and external consultants. The project is divided into work packages managed by coordinators. In addition to the project implementation team, many HEP ODS employees were also engaged in the implementation of the equipment installation activities.

Indicators set up in the Smart Grid Pilot Project Feasibility study are:

- Losses in the distribution network in which the concept of "advanced networks" is applied (of the total electricity consumption at the distribution level)
- The average duration of forced interruptions per end customer, due to downtime in the MV network
- Energy efficiency: Number of additional energy users connected to smart grids

Project critical success criteria are not explicitly in line with SDG 7 indicators which provide for measuring the contribution to the goal in the field of energy. Further, they are also out of any other indicators explicitly determined for SDGs 1-17.

Can we, therefore, claim that this project does not contribute to SDGs, even though it is a capital project of investing in smart grids in the field of electricity distribution or, although it is not in line with key indicators, still has at least indirectly affected contribution to SDGs?

This paper aims to assess how project teams perceive the integration of different UNSDGs in electricity distribution sector projects, particularly in the case study project - The smart grid pilot project.

Based on the literature review the following hypotheses were tested:

- H1 The highest perception score is given to the contribution to the SDG 7.
- H2 There are statistically significant differences of the SDGs contribution among different project team roles.

2. Methods

The perception of contribution to the UNSDGs was measured on a 24 item scale including 17 items measuring contribution to each of UNSDGs, 1 item measuring total contribution to the UNSDGs and 6 items measuring contribution to the UNSDG7. The items were measured on 5-point Likert-type ordinal scale.

The online survey was conducted in May 2022. The questionnaire was distributed to 60 employees that participate in project implementation. 27 valid questionnaires were filled (return rate 45%). Descriptive statistics and bivariate statistics including independent t-test and ANONA were performed using PSPP to test the research hypotheses.

3. Findings

The data analysis of socio demographic data indicates that the majority of respondents are male (70,37%). Most of the respondents are between 30 and 39 years old (40,74%) with university education (88,89%). Almost all of the respondents work in the HEP ODS headquarters (92,59%). More than half of the respondents have an IPMA certificate (55,56%). The respondents have different roles in the project, project management (40,74%), implementation of project activities (22,22%), administration (18,52%) and project supporting functions (18,52%).

Perception of overall contribution to the UNSDG was rated with an overall average score of 3,74. The highest score (4,30) was given to the variable P9 UNSDG 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, while the lowest score (2,70) was given to the variable P16 UNSDG16 Promote just, peaceful and inclusive societies.

The hypothesis **H1** *The highest perception score is given to the contribution to the SDG 7* is rejected.

The reliability of the scale measured by the Cronbach Alpha coefficient is 0.95, which presents a high level of reliability.

Table 1 Descriptive analysis results of the perceived contribution to UNSDGs

	Item	Average score	St. Dev.
P1	SDG1 End poverty in all its forms everywhere	2,85	1,43
P2	SDG2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2,74	1,952
P3	SDG3 Ensure healthy lives and promote well-being for all at all ages	3,19	1,27
P4	SDG4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	3,15	1,32
P5	SDG5 Achieve gender equality and empower all women and girls	2,89	1,28
P6	SDG6 Ensure availability and sustainable management of water and sanitation for all	2,89	1,45
P7	SDG7 Ensure access to affordable, reliable, sustainable and modern energy for all	4,22	0,93
P8	SDG8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	3,63	1,08
P9	SDG9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	4,30	0,95
P10	SDG10 Reduce inequality within and among countries	3,67	0,88
P11	SDG11 Make cities and human settlements inclusive, safe, resilient and sustainable	4,04	0,81
P12	SDG12 Ensure sustainable consumption and production patterns	4,15	0,86
P13	SDG13 Take urgent action to combat climate change and its impacts	3,74	1,01
P14	SDG14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	3,00	1,36
P15	SDG15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	3,15	1,38
P16	SDG16 Peace and Justice Strong Institutions	2,70	1,30
P17	SDG17 Strengthen the means of implementation and revitalize the global partnership for sustainable development	3,48	1,01
P18	SDG Total	3,74	0,76

Authors' interpretation

Table 2 Descriptive analysis results of the perceived contribution to UNSDG7 indicators

	Item	**Average score**	**St. Dev.**
P19	SDG7.1 Proportion of population with access to electricity	3,70	0,82
P20	SDG7.2 Proportion of population with primary reliance on clean fuels and technology	3,63	0,88
P21	SDG7.3 Renewable energy share in the total final energy consumption	3,70	0,95
P22	SDG7.4 Energy intensity measured in terms of primary energy and GDP	3,67	0,68
P23	SDG7.5 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems	3,56	0,93
P24	SDG7.6 Installed renewable energy-generating capacity in developing countries (in watts per capita)	3,85	0,99

Authors' interpretation

Perception of contribution to the UNSDG7 was rated with an overall average score of 3,69. The highest score (AS=3,85) was given to the variable 24 UNSDG indicator 7.6, while the lowest score (AS=3,56) was given to the variable P23 UNSDG indicator 7.5.

The results of bivariate analysis indicate that differences in perception of overall contribution to the UNSDGs are small and statistically not significant among most of socio demographic groups of respondents. The significant differences were found between different roles of respondents in project implementation ($p < 0,05$), including respondents working in implementation of project activities (AS=3,00) and project supporting functions (AS=4,40, p=0,07) and project management (AS=3,91) and implementation of project activities (p=0,045).

The statistically significant difference is also found in the perception of the different project implementation roles to the UNSDG7 ($p < 0,05$), including respondents working in implementation of project activities (AS=3,50) and project supporting functions (AS=5,00, p=0,033)

The hypothesis **H2** *There are statistically significant differences of the SDG contribution among different project team roles* is partially rejected.

4. Research implications

There are some limitations of this study that should be considered in future studies. The main limitation of the research is a relatively small sample size that affects the generalization of research results.

The research is limited exclusively to the project team involved in the work on the Smart Grid Pilot project and relates to the Smart grid pilot project involved in the case study. Only several team members were previously familiar with the basics of SDGs and their specific indicators, while the rest of the respondents had no prior knowledge of SDGs. Contribution to SDGs was not mandatory during the preparation of the Smart Grid pilot project.

Further research should go in the direction of how specific education in the field of sustainable project management affects the willingness of team members to include project contributions more actively to SDGs in project development with the possibility to measure this contribution through concrete indicators. What is the role of the project management office in the development of internal processes and training of employees in the direction of thinking and including the goals of sustainable development in business policies from the project level, through the program level to the portfolio level?

Also, considering the large number of households (24,000) included in this project through the installation of smart grid equipment, it would be helpful to find out the opinions and attitudes of final beneficiaries about the sustainability of this project with a specific time lag. Also, to determine whether the project has changed the way of monitoring electricity consumption, whether it has contributed to changes in the behaviour and habits of users, and whether users believe that the above has contributed to the sustainability goals of the project. This type of research can be carried out at a time when there is a sufficient number of active users, i.e. a relevant sample, for whom the smart grid system is fully operational and where a certain amount of time has passed in which the users could recognize the differences compared to the period before the implementation of the project. The above can also ensure the analysis and comparison of results between different groups of final beneficiaries, as well as the comparison of results between countries.

5. Practical implications

The inclusion of SDGs in development projects in the electricity industry is of great importance in the overall contribution to the goals of the 2030 Agenda, and not only through SDG 7 - Ensure access to affordable, reliable, sustainable, and modern energy for all, but also through other goals as it is recognized in the case study. Smart grids are the present and the future of the electricity sector. The development of smart grids should be considered as a tool to reduce energy efficiency gaps (Pavlyk, V. 2020).

Smart grids find their application in the rationalization of electricity distribution, higher productivity, reduction of costs and losses, and greater flexibility in bringing energy to the end customers. It affects the quality and stability of the electricity network and more rational monitoring of consumption by end-users. It enables faster and more efficient digital transition. All aforementioned benefits from smart grid development contribute to several sustainable development goals. this impact can be stronger if work on 5 fields of action is encouraged internally: raising awareness, defining, monitoring, implementing, and acting (Moczek, N. et al. 2021).

The results of the research have a practical application at the level of HEP ODS project portfolio management and preparation of new projects whose indicators will be harmonized with the indicators at the level of national monitoring of contributions to SDGs. At the level of portfolio monitoring and management, the HEP ODS project management office will standardize the approach of including the contribution measurement of each individual project to SDGs, as well as the contribution of SDGs to the entire portfolio level, i.e. business strategy.

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Osijek-Koteks d.d. - Potential Analysis and Recommendations for Digital Transformation

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Abstract:

Osijek-Koteks d.d. recognized their need for a systematic and structured digitalization of company business to further the growth and the development of their organization. The objective of the digitalization would be to create the conditions in which they could adequately respond to the development dynamics of technology and digital solutions and consequently to the growing competition and market demands in the future. Hence, Osijek-Koteks d.d. began its transformation journey with an analysis of internal potentials for digital transformation. An analysis of business areas was conducted to assess the current situation. In cooperation with the representatives of sectors and services, more than 25 workshops were organized. These workshops analysed the business processes, identified the challenges in daily activities and defined potential opportunities for improvement. In addition, a study of trends in the construction sector was conducted that highlighted closely related examples of the application of digital technologies in the market. About thirty potential initiatives were proposed, evaluated and prioritized as a result of the implemented activities. Based on all the information collected and the implemented prioritization, an indicative implementation plan has been proposed, i.e. a high-level Roadmap with guidelines for digitization and an overview of funding opportunities from EU funds. Conclusion: Based on the current-state analysis, it was determined that Osijek-Koteks d.d. has a high-quality basis for improving the efficiency of internal processes and administrative support by expediting the circulation of internal documentation. In the first phase of the digital transformation, the focus was placed on upgrading the core system of the business and developing the electronic business operations in the organization.

Keywords: *digital transformation; digital technologies in construction sector; improving the efficiency of internal processes*

1. Introduction

Globalization and accelerated technological development inevitably affect the business of organizations that are forced to modernize and adapt their existing processes and transform a particular business segment to keep pace with the upcoming trends.

The digital transformation of business implies the transition from the traditional way of doing business by applying digital technologies and new business models that aim to improve the performance of the organization as well by adapting to the new modern environment faster.

Therefore, Osijek-Koteks d.d., one of the oldest construction companies in the Republic of Croatia, in line with maintaining a competitive position and enabling further development, recognized the need to analyse the potential and to define the recommendations for digital transformation.

An analysis of the current state of business processes and IT tools was conducted as a part of the project. The best industry practices and current business needs, requirements, capabilities and aspirations of the client were defined based on the results of this analysis, as well as the guidelines and recommendations for digital transformation.

In cooperation with the representatives of Osijek-Koteks d.d., more than 25 working meetings and workshops were held at which the analysis of business, technological and application architecture was conducted at high level. A framework and guidelines for digital transformation have been defined based on the current state.

2. Overview of trends in the construction sector

New technologies, such as artificial intelligence (AI), the Internet of Things (IoT) and Blockchain, as well as systems and solutions that ensure differentiation from market competition, business optimization and long-term cost savings are being increasingly introduced in the construction sector.

2.1. New trends in the construction sector

In the last few years, it has been noticed that the construction sector is constantly being digitally transformed, and some new trends have been emerging in the market recently. Some of the differentiating factors are highlighted below:

- Construction sites generate a huge amount of data. Organizations that can process data quickly and effectively gain an edge over the competition.
- Optimization and automation of business processes using RPA tools is increasingly used in everyday business.
- Creating 3D models, virtual tours of the buildings and visualization of the construction projects in their initial phase reduce potential errors in a later design.
- Drones or unmanned aerial vehicles (UAVs) are used to inform about the construction strategy and for continuous monitoring of the construction site.
- Breakthroughs in cybersecurity and data privacy through new and unexpected channels are becoming more common.
- The circular economy is a topical issue at the sector level.

Selected new trends in the construction sector are singled out and presented in more detail below.

2.2. Application of digital technologies in the market

Before deciding on the implementation of digital technologies, it is necessary to analyse the way in which a particular technology works and also the potential benefits of its application. The following are 13 technologies that mostly contribute to the creation of added value and further growth and development of companies within the construction sector.

ERP:

- Enterprise Resource Planning (ERP) systems are designed to plan business resources that include all standard business functions and can adapt to the specific needs of the organization.

- ERP system is a technology that integrates all construction business processes such as accounting, payroll, procurement management, inventory management in one database and takes care of all business components by removing paperwork and making the workforce more productive.
- The application of ERP software packages contributes to a significant improvement in the quality of overall business management.
- The intention of ERP is to establish an integrated information system based on a single database and to ensure that key business data is entered only once, while access to the data is provided at certain levels, in accordance with business needs.
- ERP software for the construction industry maintains all the necessary data or information on projects, profitability, conversion and revenue generation.

Cloud solutions:

- The cloud solution is the practice of using a network of remote servers located on the Internet to store, manage and process data instead of using a local server or personal computer.
- The use of clouds in the construction industry is extremely attractive due to the regular change of employees and the frequent setting up of new locations on the construction site. Many employees need better access to the organization's data to support timely, well-supported decision-making and reporting during fieldwork.
- Traditional client / server software solutions allow users to access this information from specific locations, but cloud technology has provided new capabilities that allow instant connections to be established outside of these traditional pre-configured servers. With the help of the cloud, it is now possible to access information and reporting functions from anywhere in a very secure way - wherever the Internet can be accessed.
- Construction companies have a unique opportunity to take advantage of the cloud as it provides greater freedom and ease of access to information anytime and anywhere.

BIM - Building Information Modelling:

- BIM in construction represents the use of digital 3D models during the construction process.
- Building information modelling is a complex procedure that involves interacting with information from different stages of construction and project management in general.
- The result of using BIM is an information model of the building that includes granular pieces of information about how it was built, the history of decisions made, at what stages and other critical information.
- On site, employees use mobile devices to access 3D models that allow them to visualize the finished product and see how it interacts with the current construction site conditions.
- The two main areas in which BIM makes the most noticeable difference are development and simulation, as well as visualization and collaboration.

Unmanned aerial vehicles – Drones:

- In just a few years, drones have almost transformed the construction industry and now play a significant role in the process of project planning, field recording and overall data collection.
- They are ready to perform many functions because they can record video, capture high-resolution images and perform remote laser scanning by operators on the ground.

- Drones are extremely popular in the construction industry since they provide an aerial view of the construction site at a relatively low cost.
- Drones provide a simplified, cost-effective and faster way to provide an up-to-date aerial view of the terrain. This is exactly what made them quite popular in the construction industry.

VR - Virtual reality:

- VR gives teams the ability to “see” a project site without physical presence and allows a real-time collaboration, within a shared environment where they can literally point out the details and problems, ask questions, and make immediate change decisions.
- Improves deadlines by providing faster feedback. It also reduces the time required for finishing, improving the accuracy and the level of detail of the project.
- The benefits of VR are especially relevant when building in difficult or remote locations, where teams can communicate over long distances, and the site conditions make visits challenging.
- Simulate the entire building and check the budget of the new construction process for a faster implementation.
- Key benefits of using VR are training, security, virtual tour, review of plans, and budget evaluation.

AR - Augmented reality:

- Using advanced camera and sensor technology, AR combines the physical environment with computer-generated information and presents it in real time.
- While virtual reality is an exclusively digital experience, augmented reality merges the real and the digital into one environment. AR projects 3D images on a person's physical environment while passing with a mobile device or a special helmet.
- Using GPS and cameras, the AR unit can geospatially present data in real time, updating and displaying the necessary information as the user moves through the space of the building.
- Information such as schedules, operational details and structural plans are easily accessible, allowing users to automate the construction process and make on-site decisions. AR can place certain details and elements on the construction plan so that stakeholders can understand the project better.

Internet of Things (IoT):

- IoT is a network of embedded sensors and devices capable of sending and receiving data on changes in the environment over the Internet.
- The Internet of Things is used in the construction industry to simplify processes, reduce waste, increase safety and ultimately save money and time.
- Development in the construction resulting from the long-range and the low-power technologies enables smart construction sites by implementing sensors that monitor key performance indicators, equipment movement and inventory utilization rates.
- Also, IoT allows employees to be up to date with important information such as equipment condition assessment, vehicle speed, tyre pressure and GPS tracking.

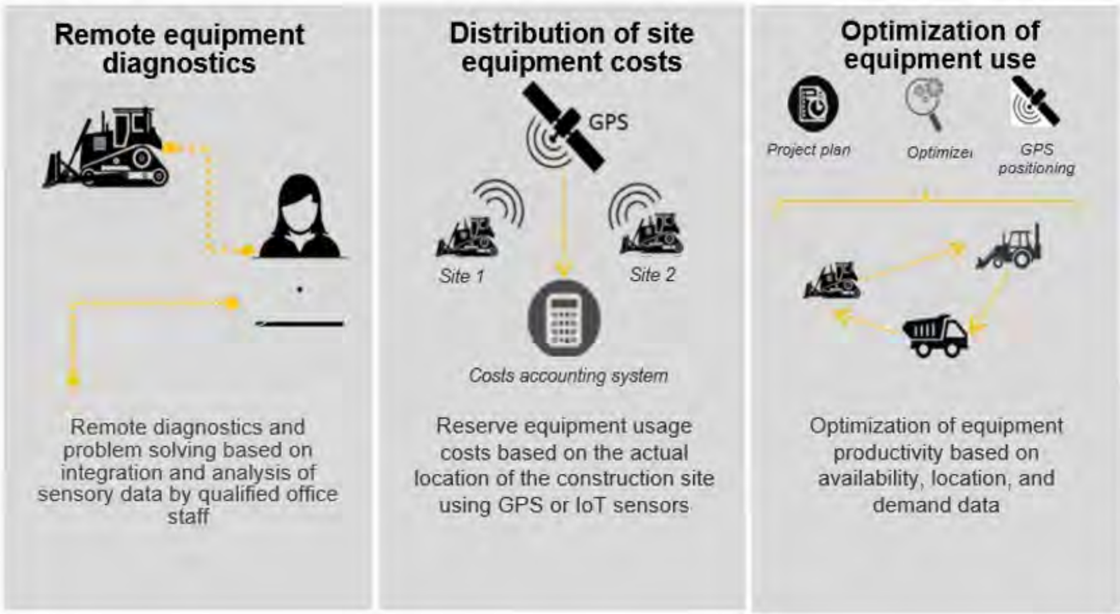

Figure 1. Equipment management system in the construction industry

The Figure 1. shows the mutual exchange of IoT sensor data implemented on vehicles and work equipment of the organization that undertakes to effectively monitor the location and condition of assets in order to optimize operational processes and performance of these vehicles and work equipment.

The collected data enable automated preparation of reports about the location and the condition of the vehicles, consumption, derived results based on which the organization can optimize its own business.

Blockchain:

- A blockchain is a distributed book of information, such as transactions or contracts, that is stored through a computer network. This information is stored chronologically, can be seen by the user community, but is decentralized and is not usually managed by a central body such as a bank or government, and once published, blockchain information cannot be changed.
- Supply chain management, dynamic monitoring of workflows, schedules, costs and payments require enormous efforts and resources. In addition to these challenges, construction projects experience different forms of errors, delays and accidents at different stages and with different intensities.
- Blockchain enables a simplified procurement process by reducing the high level of fragmentation and the level of complexity of large projects. Recording the origin of materials can reduce the amount of waste and boost the quality of products and services with a high level of responsibility. Such systems can increase predictability in terms of the procurement, but also in the case of the realization of the entire project.
- Blockchain can be used in the construction sector to create smart contracts, optimize BIM usage, make payments and manage the supply chain.

Big Data and AI:

- Big Data is a large amount of data sets that cannot be stored, processed or analysed using traditional tools. As time passes and more data becomes available, machine learning makes data analysis systems “smarter”. With the help of artificial intelligence and machine learning, data generated from images taken via drones, mobile devices and security sensors can be analysed to gain insights that will help the organization operate more efficiently.

- Data analysis tools are designed to extract information from large data warehouses and make it available to everyone involved in the construction process, including contractors, architects, retailers and customers.
- Big Data and artificial intelligence are used at every stage of the construction process to increase efficiency and productivity. They can also be used in the construction sector to analyse data on past tenders, optimize bid and price selection, design and maintenance.

Analytics and reporting:

- Analytics is the process of collecting, analysing and tracking data to improve capital project outcomes, reduce risk and detect critical insights using real-time data and automated construction reports, consolidated from multiple sources.
- By connecting these data sources, construction companies can simplify the entire construction process by using analytical tools and combining financial data, corporate data, schedules, deadlines and other key elements of successful construction project management.
- Visualizations enable simple and effective reporting of key performance indicators at flexible levels of reporting.
- Construction analytics solutions analyse real-time data against performance thresholds.

RPA - Robotic process automation:

- Robotic Process Automation (RPA) is a set of software tools that automate a wide range of business processes.
- By taking on repetitive, day-to-day, long-term tasks, RPA can reduce costs, increase efficiency and productivity, minimize errors and enable employees to focus on higher-priority activities. RPA is used in the construction industry to reduce costs, prevent errors and speed up process implementation. This is done by integrating robots into regular business processes that are extensive, structured, repetitive and take place according to certain rules.
- In its business, the construction company Skanska uses 5 robots that have taken over activities such as handling and processing customer invoices, payments, sending reminders and managing accounting journals. Using RPA technology, Skanska has managed to automate 35 processes comprising more than 10,000 saved working hours each year (Uipath, 2022).

Low-code and no-code technologies:

- Codeless development is a set of tools, applications or platforms that allow you to build a relatively complex application without knowledge of a programming language.
- Instead of relying on programming, low-code platforms simplify application development with techniques such as *drag-and-drop* and visual guidance. It means that anyone in the organization, regardless of their technical expertise or abilities, can create business applications and thus relieve the IT professionals in the organization.
- Low-code / no-code technologies can be used in a variety of business processes to optimize workflows, predict financial results, and propose business decisions. Such technologies offer development environments that enable organizations to build

applications quickly, eliminating the need for advanced knowledge of programming languages and coding.

3. Current state analysis of Osijek-Koteks d.d.

As part of the analysis of the current situation, first was conducted a self-assessment of digital maturity which is based on an independent evaluation of Osijek-Koteks d.d. according to defined criteria for assessing maturity and digital intensity index.

An initial analysis of existing documents and work instructions at the level of individual services was conducted, followed by workshops with representatives of individual sectors and services, which jointly analysed key business processes, discussed challenges faced by employees of departments and services and presented identified opportunities for improvement from an internal perspective.

3.1. Digital maturity assessment

3.1.1. Digital compass for 2030

In March 2021, the European Commission published a systematic plan for digital transformation at EU level, entitled 2030 Digital Compass: the European way for the Digital Decade (Eur-lex, 2022).

Four common goals have been proposed for the purpose of mobilizing public and private subjects. The established goals focus on:

- Population with digital skills and highly qualified professionals.
- Secure and efficient sustainable digital infrastructure.
- Digital transformation of enterprises.
- Digitization of public services.

With the purpose of making Europe a "Continent with a high share of digitized businesses" by 2030, the European Commission has established three dimensions to monitor progress in the digital transformation of businesses. Therefore, goals have been set for the companies to be monitored: technology application, users and innovative companies. In addition, a fourth goal "Governance as a platform" was defined to monitor the progress of development and maturity of public services. An overview of the goals under the Digital Compass 2030 is set out below.

Table 1. Overview of the goals under the Digital Compass 2030

Use of digital technologies	Late users of digital technologies	Innovative and scale-up companies	Management as a platform
The target for 2030 is for 75% of European companies to use cloud computing services, large amounts of data and artificial	*The target for 2030 is more than 90% of European SMEs with at least a basic level of digital intensity.*	*The goal by 2030 is to encourage the development of innovative enterprises and improve access to finance, while doubling the number of*	*The goal by 2030 is to enable citizens access to key public services in the form of e-services, to provide all citizens access to medical documentation in the*

intelligence.	*"unicorns".*	*form of e-records, 80% of citizens use digital identification means.*

3.1.2. Digital intensity index

The Digital Intensity Index (DII) is a micro index that measures the availability of 12 different digital technologies at the enterprise level:

- Internet access for at least 50% of employees for business use,
- employment of ICT experts,
- providing fast broadband connection (at least 30 Mb / s),
- providing mobile devices with Internet access for at least 20% of employees,
- setting up of a website,
- development of a website with advanced functionalities,
- use of 3D printers,
- advanced cloud computing services,
- application of e-invoices in business with automatic processing,
- application of industrial or service robots,
- e-commerce traffic that accounts for more than 1% of total traffic,
- conducting internal analysis of big data.

The value of the index therefore ranges from 0 to 12. The list of these 12 indicators is reviewed and improved every year to be in line with the latest technologies and policy priorities.

For the purpose of calculating the digital intensity index (DII) of the organization, a questionnaire has been prepared that examined the condition of 12 various digital technologies at the level of Osijek-Koteks d.d.

Table 2. DII results for Osijek-Koteks d.d.

1	2	3	4	5	6	7	8	9	10	11	12
Very low	Very low	Very low	Low	Low	Low	High	High	High	Very high	Very high	Very high

In accordance with the analysed criteria, Osijek-Koteks d.d. has a low digital intensity index.

Osijek-Koteks d.d. records a low digital intensity index and although it is at the forefront in the application of certain digital technologies, there is some room for progress and for raising the overall level of digital maturity.

Although the digital infrastructure is established, communication between construction sites and administrative services is often hampered and slowed down by the lack of signal or underdeveloped public infrastructure which makes it difficult to enter data into the ERP system MARIS and thus affects the speed of documentation circulation between individual services in the organisation.

In addition, due to the prevailing mode of operation, instead of the ERP system MARIS, physical documentation is often being used. Some functionalities of the system are not fully used due to the administrative burden of the construction site and lack of time and therefore other services consequently lack certain data for processing, analysis, projection and / or reporting.

On the other hand, due to the specificities of the construction industry, global trends, recent events at the national level and the consequences of the pandemic caused by the COVID-19 virus, there is no shortage of business opportunities in the construction sector. Therefore, advertising, sales, branding and promotion through social networks segment is not in the focus of Osijek-Koteks d.d.

Opportunities for improvement can certainly be used primarily in the field of electronic business and the application and introduction of new digital technologies. By further developing and implementing digital initiatives, Osijek-Koteks d.d. can strengthen its internal capacities and improve its digital intensity index score and consequently its market position.

Digital technologies that are represented in Osijek-Koteks d.d.:

- Companies where more than 50% of employees use a computer with Internet access for business purposes
- Recruitment of ICT experts
- The maximum contracted download speed for the fastest fixed Internet connection is at least 30 Mbps
- Providing more than 20% of employees with portable devices that enable Internet connection via mobile telephone networks for business purposes
- The company has a website
- The website contains at least one of the following functionalities: description of goods or services and price list; the possibility of user customizing or creating goods or services online; monitoring order status; personalized website content for regular visitors

Digital technologies that are not represented in Osijek-Koteks d.d.:

- Using a 3D printer to print 3D content
- Procurement of medium or high cloud computing services
- Sent e-Invoices must be eligible for automatic processing
- Use of industrial or service robots
- Companies that operate at least 1% through e-Commerce
- Internal analysis of Big Data from any data source or from an external data source

3.2. Current state of sectors and services

Workshops were organized with representatives of the sectors and services to discuss the current way of conducting key business processes, the tools used and the challenges that employees face in their daily business. Proposals and initiatives were discussed that, as employees believe, would enable more efficient implementation of business processes and would ultimately optimize the work of the organization. The organisation of individual sectors and services is described below.

3.2.1. Legal, Human Resources and General Affairs Sectors

There are four services within the legal, human resources and general affairs sectors: The Legal and General Affairs Service, the Human Resources Service, the Occupational Safety and Health Service and the IT Support Service.

3.2.2. Accounting and Finance Sector

Within the accounting and finance sector, there are four services: The Accounting Service, the Payroll Service, the Treasury Service and the Controlling Service.

3.2.3. Contracting and Procurement Management Sector

Within the sector for contracting and supply chain management, there are three organizational units: The Technical Support and Subcontracting Service, The Procurement and Marketing Department and The Contracting Legal Department. The Contracting and Procurement Management Sector is responsible for performing procurement activities, selecting subcontractors and suppliers and implementing the contracting and procurement policy in accordance with the organization's plans.

3.2.4. Operational and Technical Sector

The Operational and Technical sector oversees the operational organization on the construction sites and the coordination of the construction sites and projects. The sector also manages project risks, human resources on the construction projects and quality on the construction sites.

Operational and Technical Sector consists of:

- Director of Operational and Technical Sector
- Assistant Director of Operational and Technical Sector
- Technical Preparation Service
- Department of Transport, Construction Machinery and Workshops
- Transport Department
- Department of Construction Machinery
- Workshop Department
- Concrete Production Department
- Asphalt Production and Installation Department

4. Results of current state analysis and conclusions

Guidelines and recommendations for digital transformation are proposed based on an analysis of the current state, defining the desired future situation and an overview of current trends in the construction sector. The analysis identified current digital technologies with concrete examples at the global construction company’s level.

Afterwards, from the internal perspective of the company, all identified challenges and potential initiatives were considered, the implementation of which would optimize the company by improving cost efficiency and speeding up business processes.

In accordance with the defined methodology, the prioritization of initiatives was carried out as the primary basis for defining the desired future state and Roadmap at a high level.

4.1. Overview of identified challenges and initiatives

Based on the analysis of the submitted documentation and information collected during the organized workshops, the key challenges of Osijek-Koteks d.d. were identified. Certain challenges are observed to significantly slow down the implementation of business processes, increase the amount of necessary documentation in everyday business, prevent flexibility in responding to the needs of the construction site and hinder timely insight into financial and operational indicators of the organization. The figure below highlights the key challenges of Osijek-Koteks d.d., identified in cooperation with the representatives of business areas.

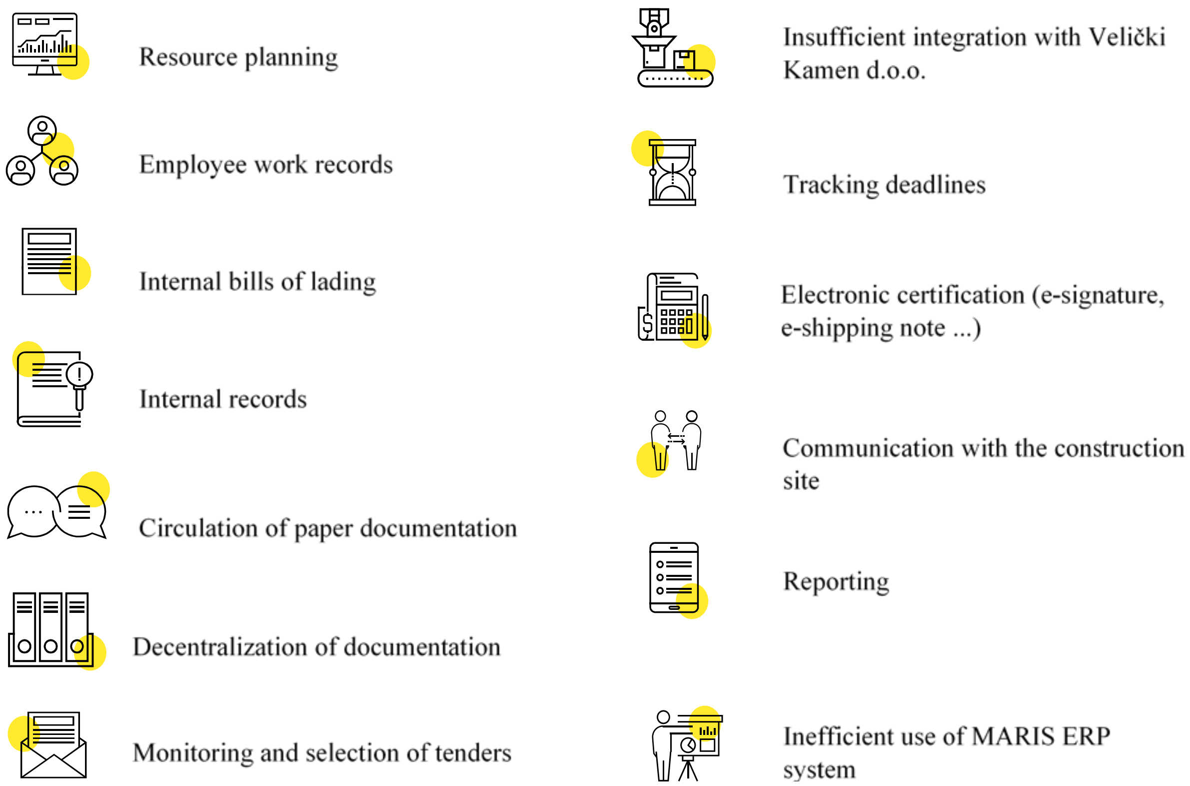

Figure 2. Identified challenges of Osijek-Koteks d.d.

Considering the challenges and, on the other hand, the needs as well as all regulatory and technical obligations of Osijek-Koteks d.d., during the analysis of the current state, in cooperation with the contracting entity, proposals for initiatives were defined. In addition, new technological trends and digital solutions in the construction industry are analysed, which will differentiate organizations in the market.

Upgrade of the existing MARIS ERP system	Site management application	Robotization and automation of business processes
Implementation of business reporting tools	Introduction of BIM tools	Implementation of retrieval and review of professional qualifications data solutions
Implementation of training programs for the use of MARIS ERP system	Application for monitoring and preparation of public procurement	Implementation of the Portal within the MARIS ERP system
Vehicle and fleet tracking system	Implementation of internal applications for support of the realization of business processes	Implementation of operational planning solutions
Employee records using cards at fixed locations	Introduction of e-Signatures	Digitization of internal bills of lading
Mobile application for registration of employees on the construction site	Implementation of document authentication functionality in the MARIS ERP system	Solution for payroll delivery to employees
Automatic timesheet check	Electronic business between Velički Kamen d.o.o. and Osijek-Koteks d.d.	Implementation of internal records for the purpose of technical preparation
Application for reporting and resolving machine failures	Establishment of an electronic archive	Centralized procurement system
Introduction of documentation on employees in the MARIS ERP system	Employee communication and collaboration internal portal	e-Tendering solution
Procurement of CAD tools and their use	Annual leave application	Requisition application

Figure 3. Identified initiatives for digital transformation of Osijek-Koteks d.d.

The key identified challenges and corresponding proposed initiatives are listed below.

Challenges:

1. The current version of the MARIS ERP system does not meet certain business needs and slows down the implementation of business processes.
2. The existing version of the MARIS ERP system prevents centralized review of individual business domains and collected documentation.
3. The lengthy process of collecting and organizing data from different data sources can result in incomplete and inaccurate reports on the current state of business processes.
4. Inefficient use of existing MARIS ERP system functionalities.
5. Inability to monitor all vehicles and machinery and lack of timely information on the location and availability of vehicles and machinery.
6. The process of recording the working hours of employees and the verification of recorded working hours itself requires significant resources
7. Dislocation of workplace prevents timely and credible records, which increases the possibility of errors.

8. The process of controlling missing values, excessive overtime and subsequent updates in cases of non-compliance of timesheets requires significant resources.
9. Employee documentation is stored in several different places - in physical registries, in the MARIS ERP system and in local folders of individual departments.
10. Impossibility of retrieving and reviewing data on professional qualifications of employees in real time.
11. The slow and unsystematic process of reviewing potential tenders and approving them is conditioned by communication that takes place by e-mail.
12. Long-term internal procurement and bidding processes of potential suppliers.
13. The parallel keeping of records in internal records and in the MARIS ERP system and the entry of the same data in different places prolongs operational processes.
14. Certain state institutions and third parties require the electronic signing of documents.
15. The processes of verification of requests and certifications for the needs of different departments are lengthy and present a significant administrative burden.
16. Slowed business processes between Velički Kamen d.o.o. and Osijek-Koteks d.d., physical exchange of documentation, decentralization of information and unsystematic review of the status of operational activities.
17. Providing storage space for contracts, invoices and other documentation that are archived in several places in different formats.
18. Impossibility of timely distribution of information at all levels in the organization.
19. Reported annual leave is not recorded in the MARIS ERP system, which affects the resource planning process.
20. Inability to review all processes within the site management, decentralized record keeping and internal records.
21. Internal bills of lading are delivered physically and are manually recorded together with the certification status and forwarded for physical signature to the site administrators.
22. The large amount of physical documentation is an administrative burden and the delivery process itself is time consuming and cost inefficient.
23. The decentralized procurement process increases initial costs, such as material procurement costs, storage costs, delivery and inventory management costs and requires additional resources in the long-term planning of project activities.
24. The requisition process is lengthy and informal as there are no standardized forms and the process itself involves physical delivery and manual approval.
25. The data entry process is time consuming and requires significant human resources.
26. Operational activities in the field of technical preparation are carried out manually without the possibility of monitoring the history and changes of individual items.
27. Non-standardized internal processes and many parties involved in communication and planning prevent agile planning and monitoring needs daily
28. The use of BIM tools becomes one of the mandatory conditions when applying for public tenders.
29. The current version of CAD tools does not fully cover the operational needs of the company.
30. Defects are most often reported by telephone and often the machine workers assess the type of defect only after going to the construction site. Historical fault monitoring has not been implemented.
31. The inability to monitor the work phase in a timely manner makes it difficult to plan project activities and requires additional resources in the organization of business.

Initiative proposed for each of above listed challenges:

1. Upgrading the MARIS ERP system
2. Implementation of the Portal within the MARIS ERP system
3. Implementation of business reporting tools
4. Implementation of the training program for the MARIS ERP system
5. Vehicle and fleet tracking system
6. Employee records using cards at fixed locations
7. Mobile application for registration of employees on the construction site
8. Automatic timesheet check
9. Introduction of documentation on employees in the MARIS ERP system
10. Implementation of a solution for retrieving and reviewing data on the professional qualifications of employees
11. Application for monitoring and preparation of public procurement
12. e-Tendering solution
13. Implementation of internal applications to support the implementation of business processes
14. Implementation of internal applications to support the implementation of business processes
15. Implementation of document authentication functionality in the MARIS ERP system
16. Electronic business between Velički Kamen d.o.o. and Osijek-Koteks d.d.
17. Establishment of an electronic archive
18. Internal portal for communication and collaboration of employees
19. Annual leave planning application
20. Site management application
21. Digitization of internal bills of lading
22. Solution for delivery of payrolls to employees
23. Centralized procurement system
24. Requisition application
25. Robotisation and automation of business processes
26. Implementation of internal records for the needs of technical preparation
27. Implementation of operational planning solutions
28. Introduction of BIM tools
29. Procurement of CAD tools and their use
30. Application for reporting and resolving machine failures
31. Application for monitoring the progress of works

5. Roadmap for digital transformation

Based on the analysis of the current state of the organization, research and review of trends and analysis of the application of digital technologies in the construction sector potential initiatives were identified to launch digital transformation of the company in cooperation with the representatives of Osijek-Koteks d.d.

The evaluation and prioritization were conducted after identifying and defining potential initiatives and the following chapters present the approach, applied methodology, results of prioritization and, finally, the roadmap proposal for the implementation of selected initiatives. General guidelines and recommendations for digitization according to the best industrial practices are presented in addition to the indicative plan for the implementation of initiatives.

5.1. Prioritization of initiatives

In cooperation with the representatives of Osijek-Koteks d.d., a workshop was held on prioritizing initiatives. The workshop analysed the results of an individual evaluation of the group of business benefit criteria and also the results of a technical analysis and overall evaluation of the group of criteria related to the expected implementation. The table below sets out the criteria and descriptions of the criteria based on which the evaluation was carried out, followed by the ranking of the initiatives.

Table 3. Review of business benefit criteria for evaluation and prioritization of initiatives

Criterion		Description
Strategic compliance		The initiative is aligned with the business strategy and supports the strategic plan of the organization
Non-financial impact	**Better departmental compliance**	Impact on the exchange of documentation and information of the services and departments involved - faster and more transparent cooperation
	More optimal implementation of the process	Impact on simpler and more efficient implementation of business processes
	Accelerate the business processes	Impact on shortening the time required for business processes
	Reduction of paperwork	Impact on administrative relief, reduction of repeated printing of identical copies of documents, etc.
Financial impact	**Expense reduction**	Impact on cost optimization (time savings, resource savings, more efficient identification of opportunities and constraints, reduced manual workload, fewer errors, etc.)
	Increasing income in the long run	Impact on increasing revenue of existing business processes
Key initiative		The initiative is key to achieving long-term benefits and the extent of the positive impact of the initiative is recognized at the organizational level

Table 4. Review of implementation challenges criteria for evaluation and prioritization of initiatives

Complexity of implementation	**More optimal implementation of the process**	**Business**	Assessing the involvement of the business sector workforce needed for the successful implementation of the initiative
		IT	Assessing the involvement of the workforce with key knowledge and skills in the IT field, which are necessary for the successful implementation of the initiative
	Complexity of implementation		The implementation of the initiative directly affects the business processes of certain services, departments, sectors or the entire organization
Number of systems involved			Number of integrations of various systems
Risks	**Change management**		Number of expected changes and subsequent requests for possible refinements during the implementation
	Top management support		The level of involvement of management and top management and the provision of strategic support to the entire transformation is key to the success of implementation and acceptance by employees
	Legal and regulatory		Legal and regulatory impact - A prerequisite for the implementation of the initiative is minimal analysis and / or the need for alignment with the legal and regulatory framework
	Business continuity		The impact of implementation on the business continuity of the organization, i.e., on the normal course of daily business activities
Time range			Time needed to implement the initiative

Regarding the results of scoring, the initiatives are positioned on the priority matrix, i.e., they are classified into one of four quadrants:

- Strategic shift (Quadrant I) - Initiatives that require significant resources or high implementation risks while the initiative brings significant business benefits and represents a strategic departure from the existing situation in the organization.
- Prioritize (Quadrant II) - The initiative brings significant business benefits, while the complexity of implementation is low. Such initiatives are considered so-called "quick-win" initiatives.
- Consider (Quadrant III) - The complexity of implementing the initiative is also low, but the initiative itself brings lower business benefits, i.e., only a certain level of value, and therefore further consideration is recommended.
- Caution (Quadrant IV) - Initiatives whose implementation is complex and / or longer and which usually involve more systems or involve significant implementation risks, while, on the other hand, the expected business benefit is relatively small and / or focused on a smaller target group within organisations.

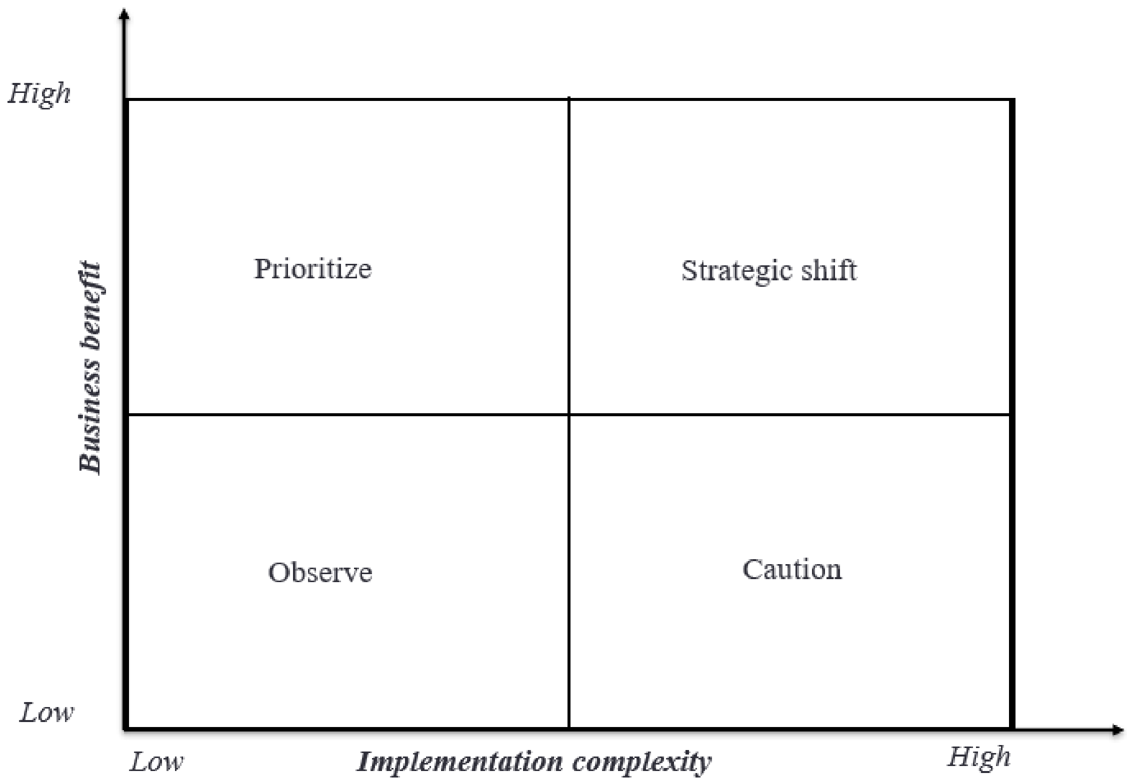

Figure 4. Priority matrix

The ranking of initiatives was conducted in the Initiatives Priority Tool. Representatives of Osijek-Koteks d.d. conducted an individual evaluation of initiatives according to the criteria for assessing business benefits, while Ernst & Young Savjetovanje d.o.o. conducted a technical analysis and evaluation of the criteria used to assess the complexity of implementation. The results of both evaluations were then combined and according to the previously presented methodology the initiatives were ranked and positioned in the prioritization matrix.

5.2. Indicative roadmap proposal

Based on the results of prioritization, and regarding the categories of initiatives, a proposal has been defined for an initiative implementation plan in three phases, which is presented in the figure below.

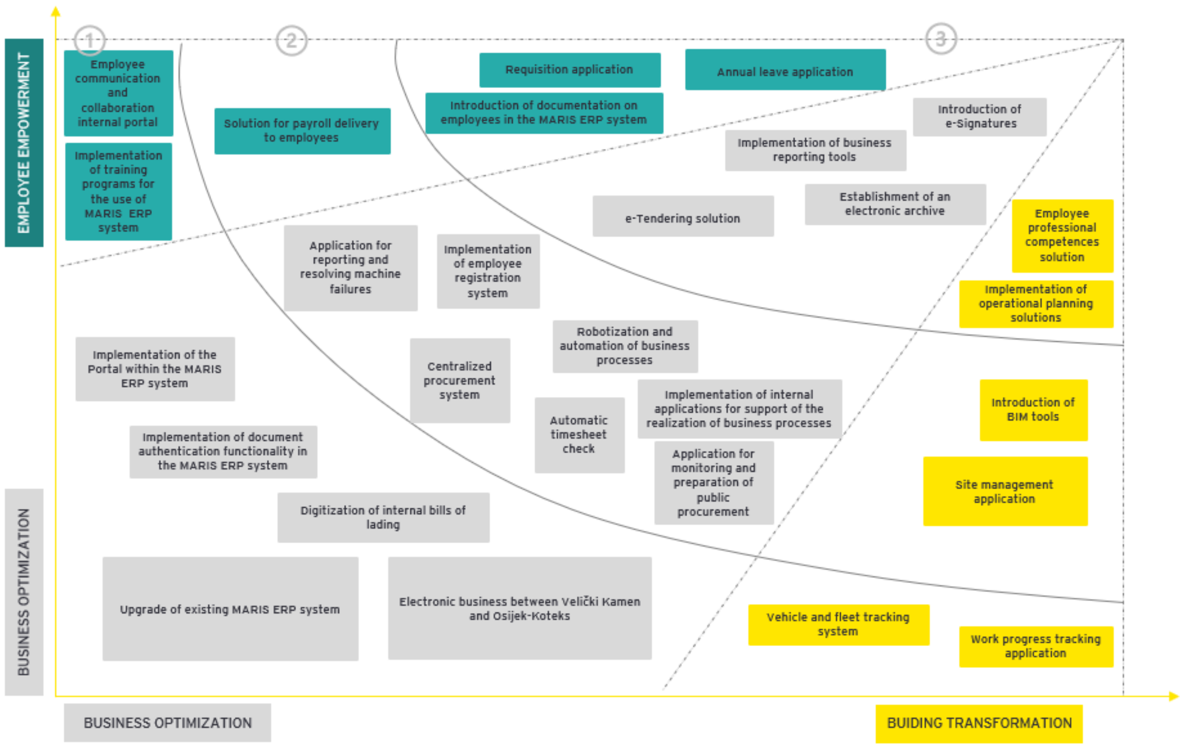

Figure 5. High level indicative Roadmap

Initiatives are divided into three categories, according to the domain / area of business that is planned to be improved:

- Business optimization - Identification and implementation of new tools and business methods that make the organization more efficient, flexible and transparent.
- Construction transformation- Implementation of solutions for optimization of key and supporting processes on the construction site and services provided by the organization on the market.
- Empowering employees - Implementation of new solutions and initiatives aimed at encouraging cooperation and increasing employee productivity.

Furthermore, based on the results of the evaluation and additional analysis, a high-level indicative Roadmap has been proposed.

In the first wave of digitalization, the launch of the implementation of strategically important initiatives is being proposed, the implementation of which will be longer and more demanding but also bring significant business benefits, which are expediting business processes, reduce bureaucracy and / or increase revenue in the future.

Therefore, in the first wave of digitalization, the launch of two strategically most important initiatives is proposed - Upgrading the existing MARIS ERP system and Electronic Business between Velički Kamen d.o.o. and Osijek-Koteks d.d. In addition, the launch of two initiatives in the field of construction transformation is proposed - the introduction of a system for monitoring vehicles and machinery, and an application for monitoring the progress of work.

The remaining proposed initiatives within the first phase are the so-called "quick-wins" and can be implemented in a relatively short period of time. In the field of employee empowerment, the key initiative is the implementation of training for the use of the MARIS

ERP system and the establishment of the internal portal for communication and collaboration of employees. The remaining proposed initiatives - Implementation of the MARIS Portal, Authentication of documents in the MARIS ERP system and digitalization of internal bills of lading can contribute to increasing the efficiency of business processes and therefore their implementation is proposed in the first wave of implementation.

Initiatives that require more detailed business analysis and / or technical preparation and that will contribute to the realization of added value to the organization in the long run are proposed for the second wave of digitalization. Divided in the defined fields, these are:

- Construction transformation - proposed implementation of an application for comprehensive site management and introduction of BIM tools due to regulatory changes and increasing requirements,
- Business optimization - proposed implementation of applications for reporting and resolving machine failures, centralized procurement systems, applications for monitoring and preparing public procurement, internal applications to support the implementation of business processes, robotization of business processes, employee records systems* and automatic timesheet checks. Applications could be implemented using low-code / no-code technology, and the recommendation is that initiatives for the introduction of low-code / no-code technology be implemented first.
- Employee empowerment - proposed implementation of a solution for the delivery of payrolls to employees.

Initiatives that will facilitate daily operations but introduction of which requires a more detailed analysis of business processes, requiring reengineering / redesign of processes and other initiatives that to a lesser extent contribute to business improvement are proposed for the third wave of digitalization.

6. Guidelines for digitalization and recommendations

This chapter presents general guidelines and recommendations for the implementation of digitization and digital transformation.

The focus of digital transformation

Following the decision to initiate digital transformation, it is necessary to keep in mind that the focus of digital transformation is not exclusively on digitalization, but also on the transformation of the organization. Ad-hoc introduction of digital solutions cannot be equated with the process of digital transformation.

Initiating digital transformation requires a structured approach, i.e., it requires systematic definition of needs, requirements, preferences and desires of the organization, determining the target future state and making decisions on implementation plan and activities that include reengineering of the business processes and / or introducing new digital solutions.

Therefore, in practice, IT or Digital Strategies and Action Plans with defined strategic initiatives are most often established in such a way that the process of digital transformation itself can be systematically monitored. It usually starts with assessing the current situation by business areas and identifying the challenges that employees face. Given the gap in relation to the target future state and based on the conclusions of the analysis, the initiatives and / or strategic projects and programs are defined with the proposal of the time frame for the implementation, i.e., with the proposal of the roadmap. Furthermore, the status of the implementation within the project management is monitored at the level of activities of each individual initiative.

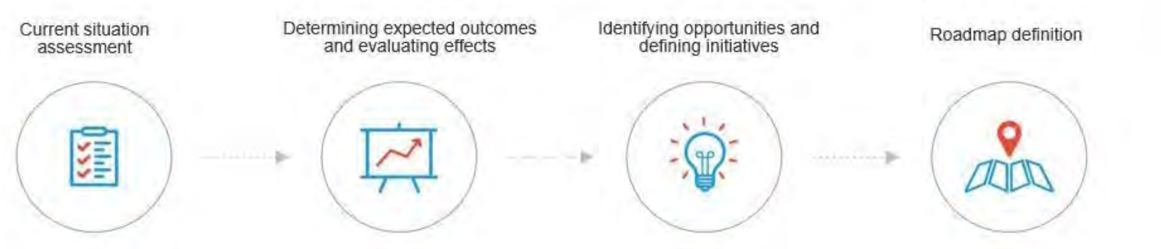

Figure 6. The process of defining the Digital Strategy and / or Strategic Digital Initiatives

Defining roles and responsibilities

One of the most common failures in the implementation of digital transformation in the organization is related to the undefined roles and responsibilities and expectations of all stakeholders involved. Given the complexity of the venture, organizations should appoint one dedicated person to be responsible for monitoring, supervising and reporting on the status of project implementation / defined transformation initiatives. In addition, the IT department / IT department manager cannot and should not be the only responsible stakeholder in the digital transformation process.

Providing resources for implementation

When defining the roadmap proposal for the implementation of initiatives, in addition to the evaluation related to business value, it is necessary to consider the complexity and assess the workload of business and IT resources in the expected period of implementation. Business continuity and day-to-day operational activities must not be jeopardized during the implementation of initiatives. Therefore, it is necessary to determine the expected engagement in a timely manner and plan activities accordingly and allocate sufficient human resources for their implementation.

Open communication and adaptation of organizational culture

The success of the digital transformation depends on the acceptance of change by employees and the speed of adaptation to the new way of working. Resistance to the introduction of changes and digitalization is a common occurrence in all organizations, but that is why it is necessary to define a communication plan for employees and timely inform employees at all levels about planned changes. It is also important to emphasize that digitalization does not mean reducing the number of jobs and that all employees will be provided with adequate support and education in the period of introducing new solutions / systems in everyday operational activities.

Management and top management support

Visible support from the Management and senior management of the organization is necessary for the implementation of the key initiatives. Resistance to change in any environment is inevitable, but employees adapt more quickly to the new business models if the potential benefits for the organization as a whole and for the employees are properly communicated and if all stakeholders are committed to support the adoption of the new business models.

Regular monitoring of trends and revision of strategic guidelines

Every organization should establish an IT / Digital strategy based on the company's business strategy. A formal document is easier to manage, communicate change, and ultimately monitor the effects of implementation itself. As a minimum, defining an Action plan is recommended as the backbone for the implementation of initiatives.

Given the rapid development of new technologies and the emergence of disruptive digital technologies on the market, it is not advisable to define a strategic direction for the long term. On the contrary, it is advisable to define the initial strategic direction (platform selection, direction of development, strategic technologies, etc.) and establish a regular audit plan based on monitoring trends, changes in regulatory and legislative frameworks, changes in market conditions, changes in end customer expectations, etc. In addition, the revision of strategic guidelines should be carried out in accordance with the achieved results of digital strategic initiatives. Therefore, it is necessary to define a set of indicators for monitoring results, i.e., key performance indicators that will monitor progress and, if necessary, correct the dynamics of implementation and the planned allocation of resources.

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Comment Procedure on the Reform of Building Act in Public Administration

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Abstract:

The subject of the examination is the impact of the comment procedure on the preparation and implementation of the reform in the form of a project in the public administration in the conditions of the Slovak Republic. To this aim, two planned reforms in the area of construction and spatial planning were selected. The first initiative planned to use the digitalization aspect in a smaller volume, while the main principle of the second initiative is digitalization, to a fundamental extent and significance. The data collected in different detail should be decomposed by the smallest squares method so that their telltal value is relevant and the attributes are comparable. The missing values will be supplemented by structured interviews. The data will be analysed, and the results verified using the content analysis method. The results show that the comment procedure has a direct impact on the possibilities of implementing reforms in the public administration of the Slovak Republic. The review of the two reforms over the last two parliamentary terms also provides insight into other attributes and opportunities that can contribute and help to the successful implementation of projects in public administration.

Keywords: *reform; project; public administration; building act; comment procedure; digitization; Slovak Republic*

1. Introduction

It is not only in current scientific papers that we find presented a number of possible reasons why projects in public administration are described as inefficient or disproportionately long-lasting. “We have been following reform efforts for several years, with one wave of measures alternated by the other. Following the political will, modern management tools must also be applied so that the whole process really works” (Marišová et al., 2021).

This is also not the case in the case of the other two attempts to amend act No. 50/1976 Coll. on Spatial Planning and Construction Procedure (hereinafter referred to as the Building Act). The currently valid 45-year building law has been amended 40 times since the 1990s, affecting twice the findings of the Constitutional Court of the Slovak Republic. However, despite many amendments, the Building Act remained in its original framework with its outdated legislative structure, arrangement of legal relations, terminology, and forms of public administration. However, the other two major reform efforts to create a modern building law have not yet implemented the effects of efficiency. Both faced significant - both in number and content - comments in standard commenting processes. This contribution set itself the aim of verifying the impact of the comment procedure on the possibilities of implementing reforms through projects in public administration in the conditions of the Slovak Republic precisely in the last two more significant efforts to reform in the field of building order, including in the context of the social order to orient reforms towards the area of digitization. “Public administration is a deliberate activity that pursues a specific objective, namely, to regulate the conditions and ways of implementing governance” (Machyniak, 2013).

These conditions have a significant impact on its real form and its feasibility capabilities in both other attempts at reform. Also because of these effects, we assume that the relevance of the topic is high not only in view of the scope of the currently prepared reform (which is under investigation) but also in the context of possible impacts on the upcoming large-scale Recovery Plan for the Slovak Republic.

The paper offers insights through the alternation of parliamentary terms as well as through the comment processes of the reform lifecycle. It brings an analogy with the processes of the lifecycle of the project and supports them with examples from the current period based on the personal experience of the realization practice of the author. It uses a combination of basic scientific methods (comparison and analysis) and project management methods. Structured interviews were also used to verify and get up-to-date data fot the comparison of the attributes of the change in the two reforms.

2. Theoretical background

According to Gibert and Thoenig (2022) reform policies are just one way to generate changes. Tracking mid-term evolutions that are unnamed reforms matters even more. A time perspective makes it easier to identify whether this or that punctuation induces public management changes or not, why and how. A series of „don’ts“ become apparent and are listed fore pragmatic managerial purposes. Slovakia has gone through, as stated in e.g. Klimovský (2010), since 1989 and thus in a relatively short period of significant changes, which included both political changes, ie the implementation of elements of democracy, consolidation of democracy, but also the division of political power, etc., and economic transformation (removal of market economy limits, expansion of private ownership, implementation of the new tax policy, etc.) and administrative changes (new structure of the public administration system, new principles of public administration, improvement of the provision of public services, etc.). Some related reform processes have already begun during the existence of Czechoslovakia, and some have not yet been completed. But still in 2018 J. Nemec (2018) draws attention to limited outcomes of Public Administration Reforms in Slovakia. According to Guogis et al. (2020), it must be borne in mind that public administration reforms are not easy to implement. Even nowadays it can be observed that a legalistic approach is preferred by some stakeholders, and every attempt to public administration reform and implementation of some new principles is accompanied with strong bureaucratic resistance. They also point out the fact, that by analyzing the drawbacks of the reforms of New Public Management a significant necessity appeared to expand the opportunities to involve citizens in governance and to refer to the meaning of participation to citizens when the transformations are made. On other hand, the authors Innes and Booher (2004) point out that legally required participation methods in the US, like public hearings, review and comment procedures in particular, not only do not meet the most fundamental goals for public participation, but they are also counterproductive, causing anger and mistrust. Both theory and practice are dominated by ambivalence about the idea of participation itself. Both struggle with dilemmas that make the problems seem insoluble, such as the conflict between the individual and collective interest or between the ideal of democracy and the reality that many voices are never heard. Patrascu (2018) comes with the view that the choice of any of the models or solutions of reform must be adapted to the realities of the country in question. The true success of public service modernization can be accomplished by applying hybrid models that combine the features and perspectives of more than one type of reform. The option for combined or mixed models seems to be the only feasible one in a context marked by phenomena of high risk for the public administration. And last, but not least, there cannot be a true reform of the public service without placing the citizens' needs and ideals at the core of the principles and values of the governance act. Bihniak and Mykhalchuk (2021) add and point out that specifically in the course of implementation of the provisions of the public administration reform it is envisaged to form such a system of public administration that will enable effective development and implementation of a unified public policy aimed at meeting the needs of citizens and ensuring sustainable development and adequate response to external and internal challenges of an environment. It was revealed that an important stage in public administration reform is the implementation of the provisions of the Concept for the Development of Digital Competences, according to which civil servants and officials performing official duties in public authorities and local governments are required to improve the quality of training to the pace of development of digital technologies.

3. Objective and methods

For carrying out this research, we used data from the submitted materials for discussion of the Government of the Slovak Republic from the open government portal of the Government Office of the Slovak Republic as well as by collecting data from representatives of the examined departments during the months of November 2021 to January 2022. The figures refer to two consecutive reform proposals for two consecutive parliamentary terms between 2016 and 2022.

Due to the nature of the research carried out, we used data from interdepartmental comment procedures in 2019 on the draft Act on Spatial Planning (hereinafter referred to as AoSP) and on the draft Act on Construction (hereinafter referred to as AoC) as well as from comment procedures in 2021 on the draft Act on Spatial Planning (hereinafter referred to as AoSP), on the draft Act on Construction (AoC) and on the draft Act amending Act No. 575/2001 Coll. on the organisation of government activities and the organisation of central state administration (hereinafter referred to as the Competence Act or CA). The comment procedures were selected because of the possibility of using current data and at the same time the possibility of comparing them with each other.

Data on reforms were obtained from public sources, from data provided by specialists at the Government Office of the Slovak Republic and from the author's own knowledge and experience during external support of the preparation of the reform in 2021.

Due to the nature of the research carried out, we have selected the following scientific method of comparison to process the data obtained and draw relevant conclusions - a comparison of the attributes of the change of two initiatives/ two reforms (see Table 1) that will allow research questions to be examined and answered, the method of analysis - we analyse primary and secondary data from the investigated branches of state administration, method of case study using evaluation of project management tools (project phases and its milestones, project triangle – scope, time, resources). By using the content of the analysis of the comment procedure, we identified the interest of relevant actors in digitalisation reforms in the specific areas addressed. At the level of predefined groups of relevant actors, we examined the frequency and overall number of comments in the field of digitisation. To verify secondary data, we used the structured interviews - the answers were provided to us by representatives of the Government Office of the Slovak Republic (Table 1).

The aim of the research carried out was to verify the impact of the comment procedure on the possibilities of implementing reforms through projects in public administration in the conditions of the Slovak Republic, and at the same time to highlight these concrete reforms to the interest of relevant actors in the direction of reforms in the field of digitisation. To this end, we have identified two important reforms, the implementation of which we are examining:

1. The reform of the building code - the new Building Act submitted for discussion by the Government of the Slovak Republic in 2019 (hereinafter referred to as NBA.1) from the areas of spatial planning and construction from the workshop of the Ministry of Transport and Construction of the Slovak Republic.

2. The reform of the building code - the new Building Act submitted for discussion by the Government of the Slovak Republic in two steps in 2021 and 2022 (hereinafter referred to as NBA.2) from the areas of spatial planning and construction from the workshop of the Government offices of the Slovak Republic in cooperation with the Ministry of Transport and Construction of the Slovak Republic.

For their examination, we have identified the following research questions:

Research question 1: Does the comment procedure have an impact on the preparation of reform in public administration?

Research question 2: Does the comment procedure have an impact on the implementation of the reform in the form of a project in public administration?

Research question 3: To what extent do the actors involved express an interest in reforms in the context of the digital transformation in the context of the comment procedure?

The two reforms examined have so far brought two initiatives/ projects to the public administration, which are under examination, when the comment procedure (preliminary, interdepartmental) was launched, thus requiring extensive human effort and resources, at least at the preparation stage.

In view of the fact that both reforms are based on the need for draft new laws, the so-called project phases have been used for our examination purposes - in line with world project management standards - and to compare the reforms in question in the high level plan as follows:

1. Preparation phase: start of the initiative (reforms) from the first work proposal to the approval in the Government of the Slovak Republic (inclusive),

2. Initiation phase: deliberations in parliament, after approval and non/signature of the President of the Slovak Republic (inclusive)

3. Implementation phase: from the entry into force of the legislative change - implementation project/ programme – implementation of the subject matter of the change, training of affected employees and stakeholders up to the handover into operation

4. Closing phase: several months of post-deployment support (in case of deployment of a new information system, or its modifications by the so-called hyper-care phase), elimination of deficiencies and reservations, external communication, takeover into full operation by the change owner/ sponsor.

The data collected in different detail should be decomposed by the smallest squares method so that their telltal value is relevant and the attributes are comparable. The missing values will be supplemented by means of a survey to the employees of the department concerned in the form of a structured interview. The data will be analysed, and the results verified using the content analysis method.

4. Results

In terms of the data obtained, we have reached the following conclusions by analyzing and comparing the data. In Figure 1 on the timeline, we describe the progress of reforms on the timeline during each parliamentary term.

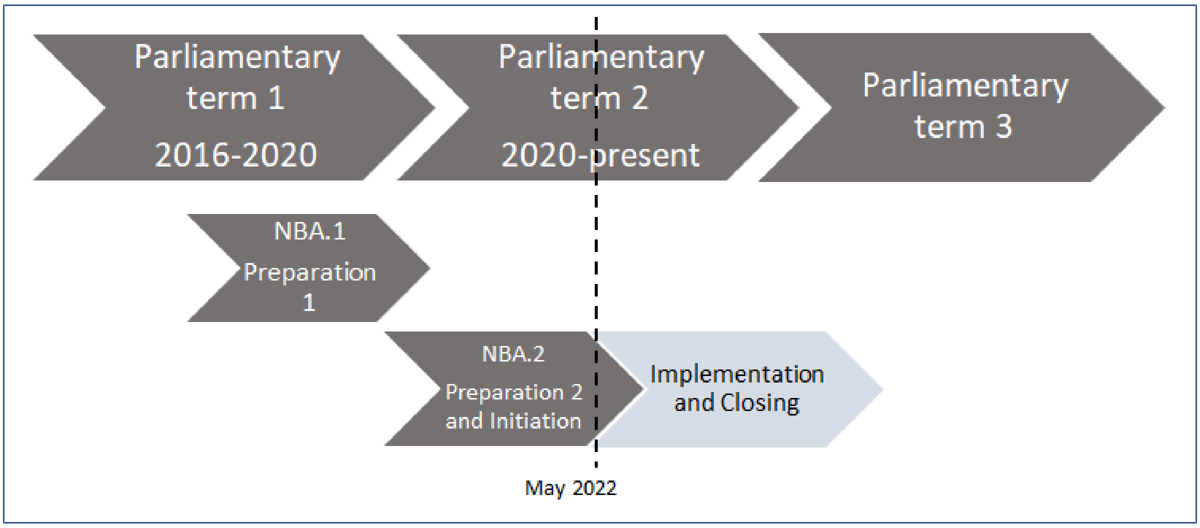

Figure 1: Two reforms in two parliamentary terms (source: author's self-processing, 2022)

Figure 2 shows the life cycle of the reforms under examination and points to the completion of the project in a particular parliamentary term. We use and illustrate here the division of individual initiatives into phases using project management methods.

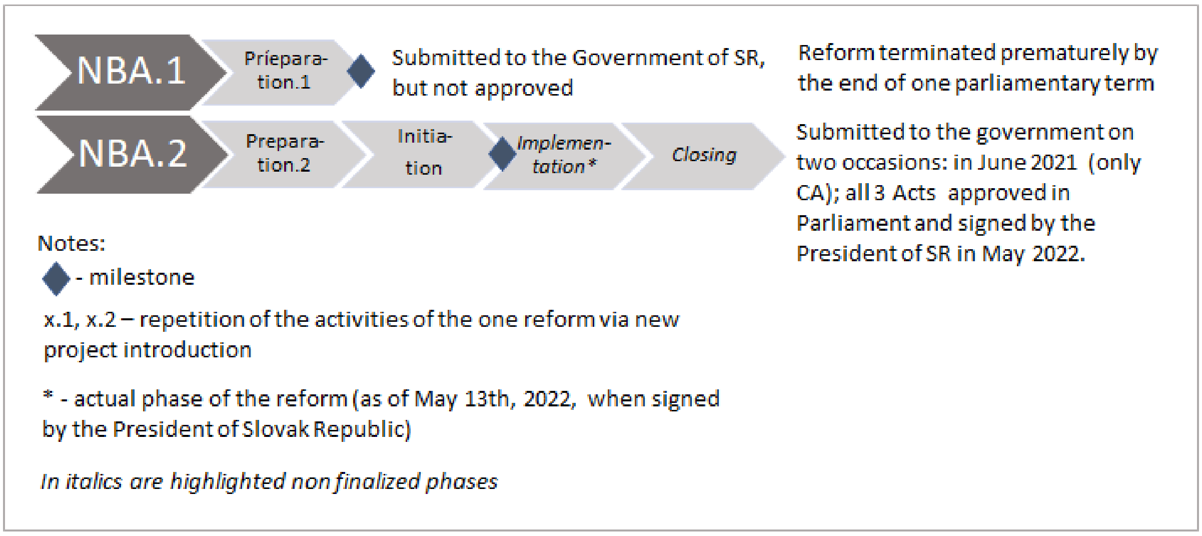

Figure 2: Life cycle of the two reforms (source: author's self-processing, 2022)

The data characterizing the parameters of the change to the two reforms are arranged for comparison options in Table 1. The first column lists the attributes of the change being studied. The first row in the second and third columns bears the title according to the description of the specific reforms that have been the subject of our examination.

Table 1 Comparison of the attributes of the change in the two reforms (source: own processing of the authors)

Attribute of the change/ Name of the reform	**NBA.1**	NBA.2
New Law needed/ number	Yes/ 2	Yes/ 2
Amendment of the existing Law/ number	no	Yes/ 1
Use of legislative intent	no	no
Reaching a pre-agreement in coalition before preparing reform	no	no
The key comments had an impact on government submissions / government approval	Yes/ not approved	Yes / repeated comment procedure = more than 6-month delay. 3 draft laws, divided into two cabinet meetings.
Preparation until implementation (until the end of the project) in 1 parliamentary term / affected by the comment procedure?	No/ yes	No/ yes
Planned time to implement changes (including IT changes/ digitisation) / affected by the comment procedure?	2 years/ no	5 years/ yes, partially prolonged by processes of the public procurement
Hypercare support after implementation and deployment of IS planed / affected by comment procedure?	Yes, 3 months/ no	Yes, half a year / no
Human resources available/ influenced by the comment procedure?	Partially/ yes	Partially/ yes

Financial resources available during preparation/ implementation	Partially/ n/a (not passed approval)	Partially/ tbd (not implemented yet)
Difference from V.1: content, scope/ influenced by the comment procedure?	n/a	yes, extension/ yes
Difference from V.1: time of implementation / affected by the comment procedure?	n/a	yes, both delay in effectiveness and extension/ yes, extended by public procurement processes
V.2 took advantage of V.1 results	n/a	yes
Number of entities involved in implementation	Up to 10	More than 10

When processing Table 1, we considered related attributes such as the number of innovations of laws and other forms of law, the time frame, the necessary resources (human, time, etc.), the frequency of entities involved and the existence of a real difference from the previous situation. The results presented in Table 1 were processed based on data obtained from interviews with representatives of the Government Office of the Slovak Republic.

The quantitative data on the comment procedures of the two reforms, which are examined by Act, are recorded in Table 2 below.

Table 2 Comparison of comment procedures per Act of both reforms (source: draft laws - own processing of the authors)

EVALUATION OF THE INTERDEPARTMENTAL COMMENT PROCEDURE/ Initiative name and its Act	**NBA.1 AoSP**	**NBA.1 AoC**	**NBA.2 AoSP**	**NBA.2 AoC**	**NBA.2 CA**
Number of comments raised, of which essential	907 /473	1801 /1045	1126 /754	2008 /1347	168 /66
Number of comments evaluated	907	1801	1126	2008	168
Number of comments accepted, of which essential	341 /154	465 /214	334 /197	776 /441	102 /34
The number of partially accepted comments, of which essential	341 /154	465 /214	205 /149	519 /408	26 /15
Number of comments not accepted, of which essential	264 /132	811 /474	566 /392	665 /461	40 /17
Number of entities with comments	47	60	54	62	23
Number of non-commenting entities	17	12	13	13	21

To be able to find out the interest of the actors about the digitization topic, we chose the recent reform NBA.2 and one out three proposals of the act - the AoSP - from this proposal we used the table for evaluation of the factual comments - as the data basis for the further processing.

As the first step we used the list of all actors and out of those we selected actors who raised at least one comment. On Figure 3 we can see 67 as a total number of all entities (hereinafter actors) involved within the comment's procedure for the AoSP of reform NBA.2 and its split. There were 54 actors, who raised at least one comment - we named them "active actors". Out of these 54 active actors there were 21 actors (38%) whose comments were explicitly related to the digitization areas/ topics. In case we put those 21 actors in relation to the whole group of involved actors, we see 31% of actors (21 out 67) who were active within comment procedure with comments explicitly aimed on the digitization topics. (Figure 4).

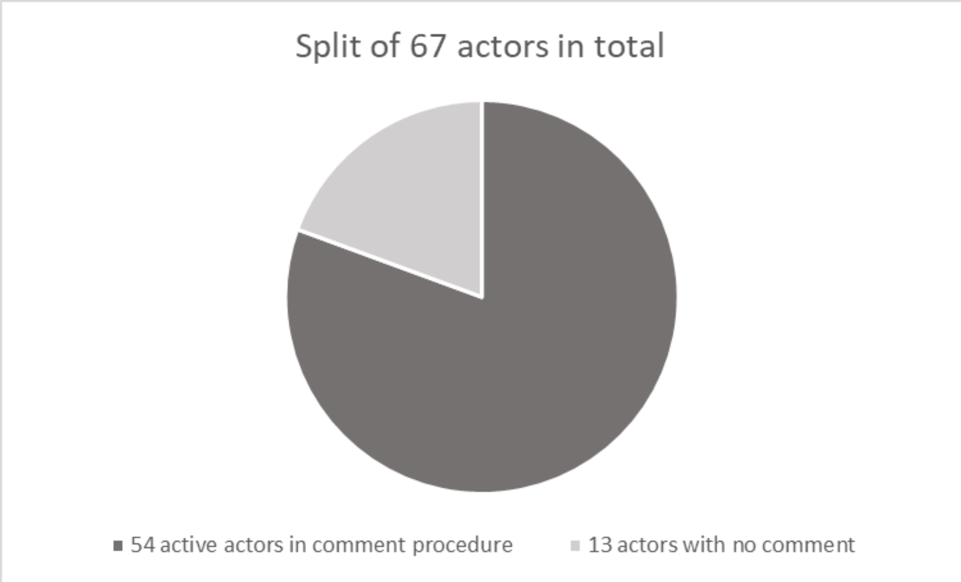

Figure 3 Split of actors of NBA.2 – AoSP (source: Draft law of Spatial Planning - own processing of the author, May 2022)

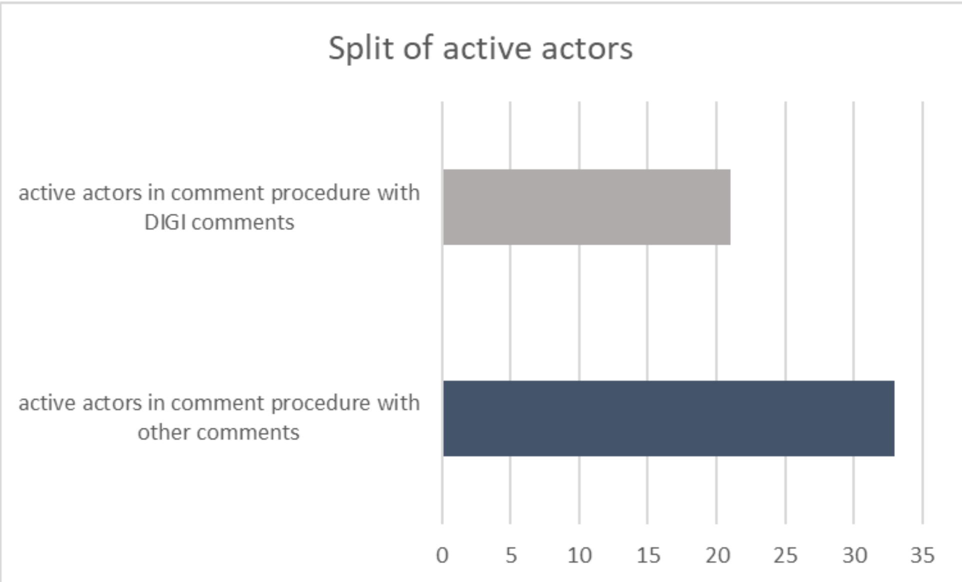

Figure 4 Split of active actors (source: Draft law of Spatial Planning - own processing of the authors, May 2022)

As the second step we went through all 1126 comments where we looked for comments explicitly aimed on the digitization topics. The outcome is visible on Figure 5, where we can find the split of grouped comments: a smaller column (on the left) represents 67 comments explicitly aimed on the digitization topics and the rest of 1059 other comments (column on the right side), those we did not investigate further.

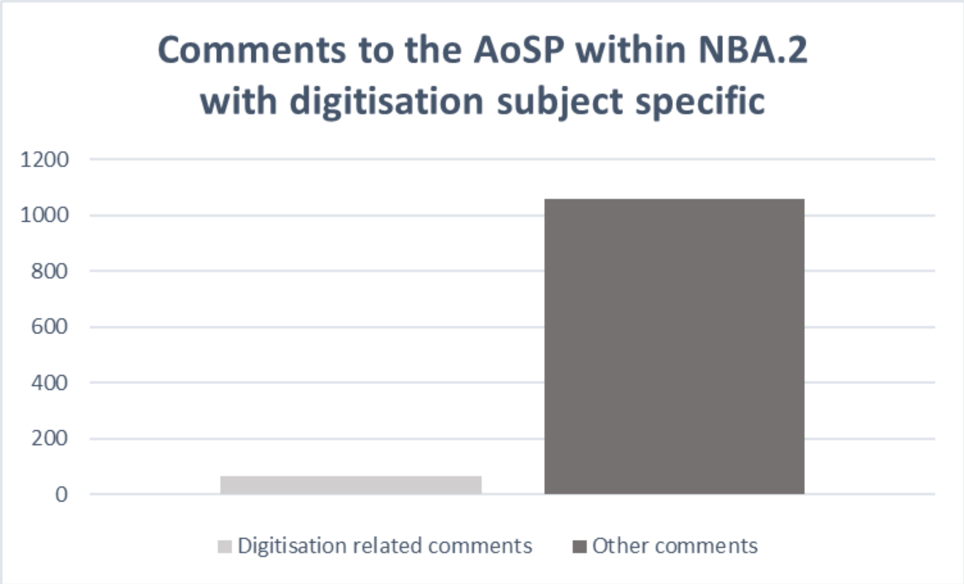

Figure 5 Number of digitisation comments of NBA.2 – AoSP (source: Draft law of Spatial Planning - own processing of the authors, May 2022)

On the Figure 6 we provide another view on the portion of the comments explicitly aimed on the digitization topics that represents 6% out of the total nr. of comments.

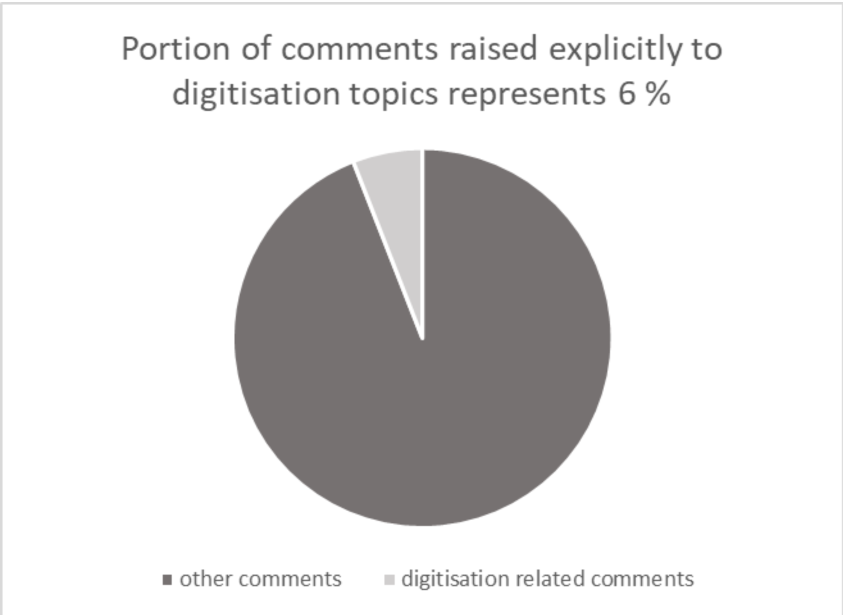

Figure 6 Portion of digitisation comments of NBA.2 – AoSP (source: Draft law of Spatial Planning - own processing of the authors, 2022)

When we investigated content via comments explicitly aimed at digitization topics and areas (67 comments), we found out that several comments had repeated - see the Figure 7. The most frequent is the comment related to the Fees/ prices for the service (9) and the comment to the IS (information system) operation and IS ownership (9). Eight comments were aimed at the Once and Only principle (incl. referencing data, data usage from other IS etc.). Area of GDPR with Security and the area of Templates in IS occurred in 3 repeating comments.

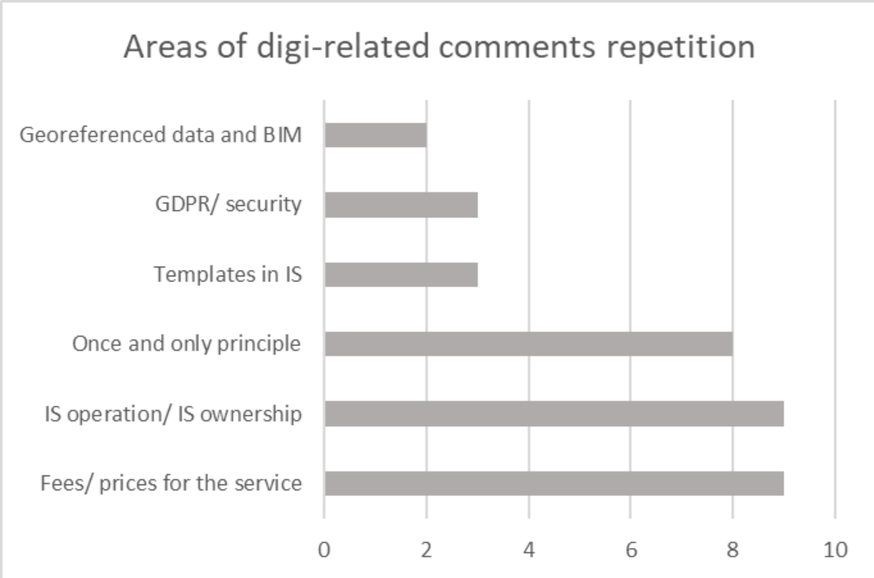

Figure 7 Areas of digitisation related comments raised by more actors (source: Draft law of Spatial Planning - own processing of the authors, 2022)

Based on the results of the investigation defined by us, we can conclude that:

Research question 1 (Does the comment procedure have an impact on the preparation of reform in public administration?) is confirmed by the examples of both reforms examined, since:

- the first reform (NBA.1) did not make use of the Legislative Intention, failed to pass a successful approval in the government ("the negotiation was suspended") and thus was not put into the initialization phase, failed to reach its initialization phase during one parliamentary term and did not proceed with the project initially launched,
- the second reform (NBA.2), did not make use of the Legislative Intention, because of a number of substantive comments that were not removed in the conflict proceedings and no consensus was reached in the coalition before the government's deliberations, the reform was divided: CA was approved with comments (conditionally) and the parts relevant to the AoSP and the AoC were moved to a repeated interdepartmental comment procedure.

Research question 2 (Does the comment procedure have an impact on the implementation of the reform in the form of a project in public administration?) is confirmed by the examples of both reforms examined, since:

- in the first reform (NBA.1), comments were received and evaluated with a number of 2708, with more than 52% (52.15%) and more than 58% (58.02%) for AoSP. Accepted comments or agreements reached from the conflict proceedings would affect the content of the reform project during implementation, but since the reform was not even launched to the initiation stage, the project did not reach the implementation stage,

- in the second reform (NBA.2), comments were received and evaluated with a number of 3302, while the substantive comments for the AoSP were less than 67% (66.96%) and for the AoC similarly 67% (67.08%). Several substantial and accepted comments and/ or agreements reached from the conflict proceedings have affected the content of the project and therefore the implementation project of the reform also requires an update of the content and time aspect of the implementation project = the project was/ will need to be rescheduled. Due to the pending substantive comments following the conflicting proceedings of the first round of the interdepartmental comment procedure, as well as the failure to reach the necessary consensus in the Coalition before the government's June 2021 meeting, the reform was divided: CA was approved with comments (conditionally) and the parts relevant to the AoSP and AoC were moved to the repeated interdepartmental comment procedure. The adjustments resulting from the incorporation of the substantive comments as well as the afore-mentioned division of negotiations required shifts in the originally proposed effects, thus demonstrating the impact of the implementation of the reform.

Research question 3 (To what extent do the actors involved express an interest in reforms in the context of the digital transformation in the context of the comment procedure?) brought these outcomes while investigating the reform NBA.2 and the proposal of law AoSP:

- 31% actors were active within comment procedure with comments explicitly aimed on the digitization topics,
- the biggest interest of these actors was focused on the 3 major areas:

1. Fees and prices for the service
2. IS (information system) operation and IS ownership and
3. Once and Only principle.

Nevertheless, since the importance of this reform is very significantly based on the benefits of digitization, only a small number of actors have dealt specifically with digitization in the comment procedure. This may, by its very nature, mean a number of perspectives, namely that, on the one hand, the reform is built so well that there is no need to deal with digitization processes anymore, or that the actors do not seem to be interested in participating in this form, or that they have underestimated the importance of the whole reform built on digitization. These aspects make room for further research in this area.

5. Discussion and conclusions

In the light of the results of the investigation, we present recommendations for further possible research. The option is to choose another, complexing of similarly large or even more reform or more reforms, which, unlike the reforms under examination by us, have used the Legislative Objective institute (idea from one out of two respondents) to compare other options, new limits, but especially effects. Another option is to compare with the V4 countries based on common historical characteristics.

One other option is the possibility of examining further attributes and greater details of the reforms examined and the reasons for their lack/success in preparation. Research can also follow the next steps and phases of the reforms under examination - in initiating and/ or implementing, closing or after some time after the implementation of the reform, when it will be possible to monitor its real effects against expectations and intended benefits. For further investigation, several interviews can also be used through a so-called 360-degree analysis of several representatives of several stakeholders.

If we were to consider reforms and instruments in the context of Central and Eastern Europe, then in line with the findings of our research, but especially for the success of the current reform, it will be necessary to apply the conscious naming and risk management brought about by another study in 2014 and that political and administrative instability is another, often mentioned contextual factor, hampering long-term systemic reform (Dan, Pollitt, 2014). In this context, we would also like to emphasize the possibility of a more permanent "sponsorship" of the change, so that the change owner – i.e. the one who brings about and leads the relevant public administration as well as other stakeholders, including the professional public from the ranks of citizens and entrepreneurs, as well as future "customers" and users of newly set rules and procedures, including technical support by the new information system, proactively and transparently led the process of change not only during the processes of legislation, but also during the implementation, preparation and support of all parties involved. For such a procedure, we recommend using and using professional program or project management using its good and useful principles and procedures.

Also on the basis of the data examined in the context of the examination of the data for the preparation of this article, we assume 'inconvenience' to obstruction of the negative stakeholders concerned in the implementation of the reform due to the planned, albeit meaningfully explained, reform aimed at centralizing the management of construction processes (AoC), which is the opposite direction to the one proposed in the 'trajectories' of the reforms examined in the public administration by the authors Boukaert, et al. (2011) - that 'state structures are restructured, e.g. towards greater decentralization'. This trajectory is currently supported by the reform brought about by AoSP proposal.

In any case, our results point to one alarming fact. Even though the comment procedure should create a relevant space for stakeholders on the possibilities and ways of implementing reforms through public administration projects in the conditions of the Slovak Republic, at the same time its point out that interest of these stakeholders in reforms those are directing in the field of digitization is low. At the same time, this finding creates a space for further research aimed at finding out the reasons for the lack of interest or rather non-participation of actors in setting the targeting of reforms to their needs.

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The Role and Impact of Project Management Mentoring: South African Community-based Projects

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Abstract:

Since 2018 a higher education institution has been partnering with undergraduate student teams and project management mentors from industry to successfully plan and execute community-based service projects in underprivileged communities, at scale. All these projects address one or more of the UN's 17 sustainable development goals. This study investigates the role and impact of project management mentoring that took place over the course of a six-month community-based service programme of 65 projects involving 325 students. A qualitative study, consisting of semi-structured interviews with 8 mentors and 12 mentees involved in the 2020 Programme, and inductive thematic analysis of the resulting data was done. The purpose of this study is to determine a) the role of project mentoring in these community-based service projects; b) what project management (PM) skills were transferred from the mentors to the mentees during the projects and c) what is the impact of project mentoring on the perceived outcomes of these community-based service projects. Findings reveal that the role of project mentoring is that of support, guidance, transference of project management skills and knowledge to the students to better execute their projects. Especially when this must be done at scale. Project mentoring facilitates the transfer of tacit PM skills, advising on the most appropriate PM templates and trains mentees to use different PM tools and techniques. The impact of project mentoring in this study is that all project results met and in some cases exceeded customer expectations. Project mentoring enhances the students' project management skills and career development while also boosting their self-confidence.

Keywords: *project management; education; mentoring; community-based service projects; South Africa*

1. Introduction

On 1 January 2016 seventeen sustainable development goals (SDGs) – adopted by world leaders in September 2015 at a UN Summit – officially came into force (United Nations, 2022). The SDGs build on the success of the Millennium Development Goals (MDGs) and aim to go further to end all forms of poverty. These goals recognize that poverty can only be ended if there are strategies that build economic growth and address a range of social needs including education, health and job opportunities, amongst others. While the SDGs are not binding, governments and state entities such as the University of Pretoria (where this study was conducted) are encouraged to take proactive steps towards the attainment of these goals through its core functions of research, education and engagement (Panyane, 2021).

The Mamelodi Community Student Projects Programme (hereinafter referred to as the Programme) was started by three UP staff members as a multidisciplinary research project in 2017. The Programme aims to address the following SDGs in a synergistic way, with little to no funding, using only volunteers:

GOAL 2: Zero hunger

GOAL 4: Quality education.

GOAL 10: Reduced inequality

GOAL 12: Responsible consumption and production

Since 2018 the Programme has been partnering with the Project Management Institute South Africa Chapter to facilitate basic project management (PM) training and to assist with recruiting volunteer PM mentors from its professional membership base. The benefit of this university/industry partnership is that the students interact and learn from practising and knowledgeable project practitioners and build on their ready-for-work skill set. The project practitioners gain professional development units (PDUs) by teaching and mentoring the students and the community is uplifted because of the project deliverables.

The Programme pairs a group of five undergraduate Bachelor of Commerce (BCom) Business Management students with a PM mentor following six sessions of basic project management training. Each mentor/student team is then required to successfully plan, execute and report on their community-based service project in an underprivileged community in South Africa. This study investigates the role and impact of project management mentoring that took place over the course of a six-month community-based service programme of 65 projects involving 325 students, in 2020. The 2020 Programme's projects focused on the needs of the Mamelodi community on the outskirts of Pretoria. Some of the 2020 project topics included pop-up street stores for the homeless, early childhood development (ECD) centre storybooks, toys and boardgames, community vegetable gardens.

The Programme was initiated in 2017 as the founding academic staff noted that the BCom students did not have the necessary project management skills to successfully plan and execute a small community-based project, yet that PM skills were valuable in almost any future career. In an extract from a book titled 'Are they really ready to work? Employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century US workforce' William Fitzpatrick, Vice President of Human Resources at Shell Trading and Shipping, states that "it is a plus when high school graduates demonstrate qualities that set them apart and reveal that they are capable of handling increased responsibilities…if they demonstrate problem-solving and project-management skills they will be given added responsibility" (Casner-Lotto and Barrington, 2006).

Literature states that there is growing shortage of skilled project managers. The Project Management Institute (2021) indicates that economic growth and retirement will increase the number of jobs that require project management skills. They predict that 25 million new project management professionals will be needed by 2030 to meet the demand. This skills shortage poses a huge risk to organisations that rely on projects to execute their strategic objectives (Project Management Institute, 2021).

A study by Berggren and Söderlund (2008) highlight the importance of project management education to both undergraduate and postgraduate students to meet the demand for project management professionals. However it is often very difficult for undergraduate students to immediately apply the theory they acquire in the classroom and link the classroom learning with experience (Pollard, 2012). The predominant "classroom-based" learning approach for project management does not fully address the project management skills that are required and desired by industry and business.

Mentoring can be used as an effective way to improve project management skills (Barnett, 2001). In this study and in the literature, skilled project managers are used to mentor and coach students while they execute real-life projects (Ramazani and Jergeas, 2015). There are however few studies that investigate the role and impact of project management mentoring, for community-based student projects, at scale (Pitts, Snipes and Carter, 2021). The objective of this paper is to investigate the role and impact of PM mentoring in the Mamelodi Community Student Projects Programme, in 2020. In addition, the paper identifies the project management skills that were transferred from mentors to mentees during the projects. The research questions of this paper are as follows:

Q1: What is the role of project mentoring in the Mamelodi Community Student Projects?

Q2: What project management skills are transferred between the mentor and the mentees in the Mamelodi Community Student Projects?

Q3: What is the impact of project mentoring on the perceived outcomes of the Mamelodi Community Student Projects?

By answering these questions, this research aims to investigate the role and impact of project mentoring in the Mamelodi Community Student Projects Programme in South Africa. Moreover, the project management skills that are transferred from the project mentors to his/her mentees during the course of the projects, are identified. This research contributes to furthering the discipline of project management education and training through this case study investigation. Also, how an industry/university partnership in the form of training and mentoring can be used to develop industry relevant skills amongst students in an under resourced country such as South Africa, at scale.

An overview of project management learning and the most important project management skills are reviewed. We then present a conceptual framework of the learning approach that the Programme uses and the method we used to carry out the study. The empirical analysis is based on semi-structured interviews with several mentors and mentees from the 2020 cohort, with a focus on the role and impact of PM mentoring for PM skills transfer. Then, the results of the analysis are discussed, followed by the conclusions, their implications, limitations, and directions for further research.

1.1. Project management (PM) learning

Many people become project managers by ‘accident’ be it through promotion and/or experience, and often without undergoing adequate project management training (Creasy and Anantatmula, 2013). For example, a person in an information technology (IT) industry may work as a developer and over the years, get promoted to a managerial position and become a project manager. Many emerging project managers find it difficult to manage projects successfully without the support of experienced or senior project managers (Ramazani and Jergeas, 2015). A study which investigated the development path of project managers, and how they learned PM based on their experiences, found that in most cases learning happened without any learning support (Savelsbergh, Havermans and Storm, 2016). This approach to PM learning needs to be the exception rather than the rule. As stated above there is a growing shortage of skilled project managers so education and training institutions need be intentional when educating and developing project management expertise (Ramazani and Jergeas, 2015).

People learn in different ways, which makes it difficult to define learning. Beach (1985, p. 22) defines learning as “the human process by which skills, knowledge, habit, and attitudes are acquired and altered in such a way that behaviour is modified”. Kolb (2013) states that learning is built on the following six propositions: it is continuous and should not be measured in terms of outcomes, re-learning, it is driven by conflicts, differences and disagreement, it involves integrated functioning of the world, it doesn’t happen in a vacuum, and it is the process of creating knowledge.

The learning process that develops project management skills is poorly understood. Yet interventions and programmes targeting PM skills are introduced in educational institutions, with limited success (Ramazani and Jergeas, 2015). There is a need to re-focus the research on the different ways in which students can learn and develop basic project management skills.

Ojiako *et al.* (2011) propose that educators need to change the way they teach students project management, by creating a conducive environment for a student to be able to apply their knowledge in practice. Moreover, educational institutions need to reconsider the way project management students integrate project management skills throughout all levels of learning.

Córdoba and Piki (2012) highlight that project management education is facing several challenges. A particular shortcoming is the students limited exposure to dealing with real project situations where they are expected to apply and develop their project management skills by reflecting on what they learned in class. This study makes use of community-based service projects to address this issue.

1.2. Project management competencies and skills

There is no consensus in the literature about specific competencies in project management (Brière *et al.*, 2015). Most authors present a list of competencies with typologies that can generally be grouped into three categories: 1) organizational and management competencies, 2) project management or technical competencies, and 3) human skills, soft skills or behavioral competencies (Crawford, 2005; El-Sabaa, 2001; Verma, 1996 as cited in Brière *et al.*, 2015). This study will primarily investigate the impact of mentoring on project management technical competencies (hard skills) and behavioural competencies (soft skills).

The project manager plays an integral role in the success of any project. To be a successful project manager, you must develop a wide range of competencies. The focus of project managers should be on results, their ability to work as a team, as well as to achieve the difficult balance between work, the emotional aspect of work and the intercultural dimension (Brière *et al.*, 2015). Brière et al. (2015) did a study to identify the competencies of 28 international development project managers in non-governmental organisations (NGOs) as well as how they used these competencies in their projects. Their analysis identified an important grouping of competencies linked to human and behavioural aspects. They identified 11 competencies of which 10 are related to human aspects. These competencies are adaptability, set of knowledge (general, international development, intercultural), communication, personal qualities, interpersonal skills, leadership, ethics, local network, knowledge, capacity building, and change management. They conclude that there is a need for the development of learning methods that go beyond project management education in enhancing project manager’s human and behavioural competencies (Brière *et al.*, 2015).

An in-depth case study investigation conducted by Taylor and Woelfer (2009) interviewed 13 experienced IT project managers from 5 different organisations. The focus of the study was on what the managers perceived as their most critical project management skills and how they had developed those skills. The results revealed that formal project management training is not enough to encourage the development of project managers, though it provides the basics for experiential learning to occur. The study also acknowledged that procedural knowledge and behavioural competency are more likely to develop in a service-learning environment. An environment where students have opportunities to practice the skills that they have been taught in a classroom setting and to get feedback and reflect on their practice (Eraut, 2000). One of the main outcomes of the Programme (in addition to uplifting disadvantaged communities through project delivery) is to develop the students project management procedural knowledge and behavioural competencies.

Project management skills are divided into two main categories: soft skills and hard skills. To be competitive in today’s project environment, project managers should have a balance of soft and hard skills to manage projects successfully (Ibrahim, Boerhannoeddin and Bakare, 2017).

1.2.1. Soft skills in a project management context

To ensure that future project managers are effective in their role, educators need to focus on the relevant soft skills of project management (Mitchell, Skinner and White, 2010; Pazhani and Priya, 2012; Poston and Richardson, 2012). These soft skills are rarely taught in project management courses. This may be because these skills are not central to project management education, but they enhance a project manager’s chances of managing projects successfully. Ramazani and Jergeas (2015) encourage educational institutions to develop the softer parameters of managing projects in future project managers, especially interpersonal skills and leadership as opposed to just technical skills. The most important soft skills in project management literature are identified. The top project management soft skills include leadership, communication negotiation, problem solving, resilience, critical thinking, conflict resolution and interpersonal skills (Jena and Satpathy, 2017; PMI, 2017). These essential soft skills are discussed in more detail below and will form part of this study .

1.2.1.1. Leadership skills

Steyn *et al.* (2016) defines leadership skills as “the ability to influence the behaviour of others to accomplish a desired activity”. The project manager’s leadership ability is very important as this ability provides direction, motivation, and creates a conducive working environment for the project team (Anantatmula, 2010). Leadership performance is identified as one of the critical attributes in determining project success or failure (Nixon, Harrington and Parker, 2012). Project managers use different leadership types and approaches depending on the type of situation at hand. Good leadership builds trust between a project manager and the project team (DuBois *et al.*, 2015). In the study leadership skills development is encouraged in the student team and modelled by the project mentor. Each student team must identify an individual that will act as the team project manager. This person is primarily responsible for setting up meetings with the mentor, taking the lead in planning the project, ensuring team collaboration and he/she is responsible for handing in all project outputs on time.

1.2.1.2. Communication skills

Communication skills are one of the most important project manager competencies correlated to project success (Alvarenga *et al.*, 2019; Gewanlal and Bekker, 2015). Moreover, the ability to communicate well verbally and non-verbally to others is the foundation of an effective project manager. Intra-project communication between the project manager and team members influences team performance through the sharing of information and the exchange of ideas (Bond-Barnard, Steyn and Fletcher, 2014). In the study communication skills are encouraged and assessed by producing the project outputs and deliverable.

1.2.1.3. Negotiation skills

Steyn *et al.* (2016) defines negotiation "as a process of bargaining and reaching agreement with project stakeholders concerning the transfer of resources, the generation of information and the accomplishment of tasks". According to Abwanzo (2013), negotiation skills are important in project management as the project manager is often required to negotiate project constraints throughout the project lifecycle. In the study intra-team negotiation is promoted, as team members are required to negotiate who is going to do what on the project. Moreover, the literature indicates that the feedback an educator gives a student demonstrates the fundamental development of the student's writing, reading and negotiation skills (Musa *et al.*, 2012).

1.2.1.4. Problem solving skills

Effective problem solving skills indicate that a person has the ability to use problem solving processes in resolving issues that arise during the project lifecycle (Keil, Lee and Deng, 2013). Early identification of issues minimizes the difficulty of resolving the problem. Project managers should encourage team members to raise problems as they happen and try to solve it themselves, before escalating it to the project manager (Steyn *et al.*, 2016, p. 291). Similarly, the Programme encourages the student teams to first try resolve project issues as a team before involving the project mentor. The mentor is there to model to the team how to solve project problems should they get stuck.

1.2.1.5. Resilience

Resilience is the ability to recover quickly from an unexpected situation (Fletcher and Sarkar, 2013). Resilience helps one respond to unexpected risks effectively (Schroeder and Hatton, 2012). Resilience requires effective project management to manage and help multiple project stakeholders to deal with predicting, responding to and recovering from disastrous events (Crawford, Langston and Bajracharya, 2013). Resilience thinking can help projects maintain their performance through flexible, systemic and context-specific approaches when faced with disruptive events or uncertainty (Rahi, 2019). The Programme develops resilience in the students as most teams encounter various stakeholder, resource, schedule and teamwork challenges during the course of their community-based project. The 2020 cohort in particular, experienced various challenges with regards to Covid 19 restrictions that impacted the planning and execution of their projects.

1.2.1.6. Critical thinking skills

Critical thinking is an essential skill for implementing a project from award approval to project closure (Lee, 2010). Dubriea and Punb (2013) found that a project practitioner's project management skills, training and development scores were positively related to his/her critical thinking skills level. There is a growing need for educational institutions to develop the critical thinking skills of project management students. Moreover, developing critical thinking skills in students plays an important role in the effectiveness of team learning (Plotnikova and Strukov, 2019). Ramazani and Jergeas (2015) encourage educational institutions to focus on developing future project managers' critical thinking for dealing with complexity and preparing these project managers to engage within the context of real-life projects. Development of students' critical thinking skills within the context of real-life projects is promoted in the Programme.

1.2.1.7. Conflict resolution skills

Conflict within a project occurs when team members have their own goals, objectives, and perspectives (Keil, Lee and Deng, 2013). Resolving conflict in a project team can be a daunting task. A project manager must have the ability to solve conflicts between team members to ensure that the project runs smoothly and is successful. In the study the student teams are encouraged to resolve conflicts themselves, however the mentor is available should they require a mediator.

1.2.1.8. Interpersonal skills

Interpersonal skills assist a project manager to clarify his/her expectations and needs, as well as to emphasize the contributions expected from every team member (Steyn *et al.*, 2016). Project managers need strong interpersonal skills to be able to actively listen and solve problems that arise when managing a project. Good interpersonal skills are essential for a project manager to establish a relationship with every team member. Programme students develop interpersonal skills by working as a team to deliver the project on time, budget and scope to the customer's satisfaction.

1.2.2. Hard skills in a project management context

Hard skills imply the more technical aspects of the project manager's role. These skills allow the project manager to create a tangible deliverable such as a work breakdown structure (WBS), project schedule, critical path diagram, earned value reports, project budgets, dashboards, and so forth, with the use of the appropriate tools and templates (Marando, 2012).

These skills include the knowledge of project management methodologies, processes, tools, and techniques used to plan and implement the project successfully (Hendarman and Cantner, 2018). Project management methodologies provide standard methods and guidelines to ensure that projects are delivered on time, within budget and scope while maintaining the quality of what it serves to deliver. Irrespective of the industry, project management methodologies can be applied to projects to improve the chance of meeting the goals of the project (Chin, Yap and Spowage, 2011). Knowledge of project management methodologies is of vital importance to both the student and the experienced project manager as it allows project standardization (Wells, 2012). In the Programme students are taught the hard skills of project management in PM training sessions during the first semester. The study investigates which hard and soft skills are transferred by the mentors to their mentees during the projects.

1.3. Mentoring in a project management context

Providing students with access to mentoring has become a priority as evidenced by the number of formal and informal mentoring initiatives that have been developed by institutions of higher learning (George and Mampilly, 2012; Weterman, 2011; Ganiron Jr, 2014). Mentoring can be an effective tool in addressing key issues and challenges facing project management students involved in managing projects. There are many definitions of mentoring but the working definition for this study is based on Niehoff (2006, p. 322) who defines mentoring "as an activity in which an individual with advanced knowledge or experience (mentor) actively provides assistance and support to enhance the career development of an individual with less knowledge and experience (mentee)".

Fagerholm *et al.* (2014) evaluate how mentoring and project characteristics influence the effectiveness and efficiency of the IT project onboarding process. Their findings reveal that developers that receive mentoring support are more effective than those that join the conventional way. Mentoring provides a connection between those who are mentored (mentees) and those who are acting as a mentor. Robinson and Reio (2012) highlight that mentors utilise their knowledge and expertise to assist students to execute their activities. Haeger and Fresquez (2016) found that mentoring impacts students' academic performance and that they learn from the experiences that their mentors share with them. The length of time a student spends working with their mentor and sharing experiences was also found to influence a students' development.

Mentoring has an impact on student career development (Jyoti and Sharma, 2015)and it has an impact on student success (Kendricks, Nedunuri and Arment, 2013; Jain, Chaudhary and Jain, 2016). Benefits for mentees include developing their technical, academic, pedagogical, and professional skills (Baran, 2016). Clutterbuck (2014, p. 26) believes that organisational benefits of implementing a mentoring programme are easier recruitment and induction, improved motivation, management of corporate culture, leadership development, improved communication, and improved retention of employees. Robinson and Reio (2012) indicated that job satisfaction and organisational commitment were higher for those who were being mentored than those who were not.

Understanding the benefits of a mentoring programme for both the mentor and mentee is critical for its success and sustainability. In this study the project mentor's crucial role in providing students with the opportunity to expand their classroom learning into community-based service projects is investigated. The impact of project mentoring, from the mentees and the mentors perspective, is also studied.

1.4. Service learning and community-based service projects

Service learning is a concept that is becoming increasingly common in the field of project management (Brown, 2000; Larson and Drexler Jr, 2010). Osman and Petersen (2013, p. 7) define service learning as a way of thinking about education and learning with an accompanying teaching tool or strategy. It asks students to learn and develop through active participation in service activities to meet defined issues in a community. Service-learning encourages students to give back to their communities through participation while also gaining practical experience. Service learning is used worldwide, primarily in fields of study such as health and education. Many health professions use service learning to instigate social appreciation and change amongst learners (Rutti *et al.*, 2016). Service learning can also be expanded to other fields of learning such as project management.

The benefits of service learning are well documented in the literature (Astin *et al.*, 2000). In a field such as project management, service learning can be used as an opportunity for students to give back to their local community, learn about various project management skills and experience the real-world challenges of managing projects. Budny, Lund and Khanna (2013) found that the challenges encountered by engineering students involved in service-learning projects are similar to those experienced engineers face in their work environment. Service learning motivates students to get involved to ensure that they form part of the solution and that they bring value to the community they are serving. The benefits of service learning projects include, the ability to solve community problems that would otherwise not be attended to, it strengthens the relationship students have with the local community with which they are partnering, offers an innovative way to execute the objectives of service learning, and provides students with an opportunity to learn about aspects of their chosen future career (Budny, Lund and Khanna, 2013). When institutions of higher learning partner with the local community in terms of project management training, it can assist in minimizing the project management skills gap while addressing community needs and providing real-world experience as advocated by Ramazani and Jergeas (2015).

2. Material and Methods

2.1. Existing framework

A conceptual framework developed by Kirkham and Ringelstein (2008) for the Student Peer Assisted Mentoring (SPAM) program was identified as providing relevant information for this study (see Figure 1). The aim of this framework is to develop learning processes that are beneficial to both mentor and mentee. It is considered relevant for this study as it also identifies three roles (academic leader, student mentor and student mentee) in the mentoring process, however for the purposes of our study these roles are fulfilled by three different entities rather than the two in the SPAM framework.

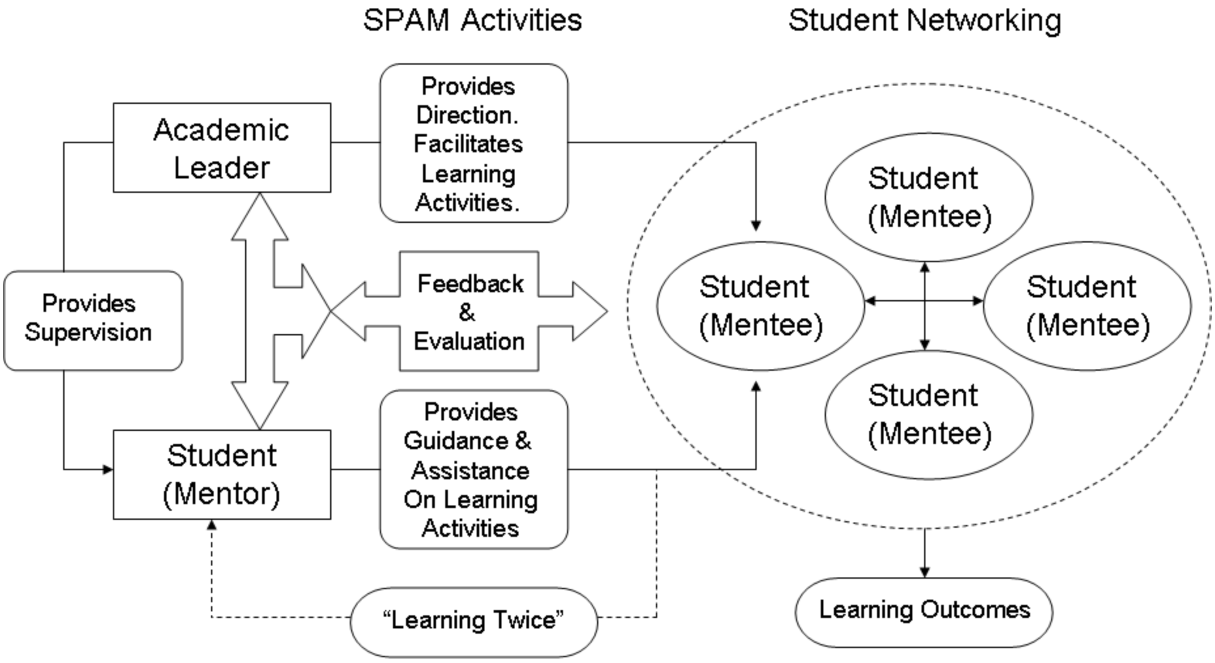

Figure 1. Conceptual Framework for Student Peer Assisted Mentoring (SPAM) (source: (Kirkham and Ringelstein, 2008))

The Kirkham and Ringelstein (2008) framework highlights the attributes of mentors as a person who must: show commitment to the mentoring process, have a good academic record, have strong interpersonal skills, be competent in the appropriate field of study, share knowledge and expertise, be patient and have respect for the learning needs of a student, be willing to assist in the student's development and have good communication skills.

Kirkham and Ringelstein (2008) recommends that mentors should be provided with basic mentoring induction training so that they can gain insight into what is expected from them. Melling and Gurjee (2013) reveal that mentoring has a significant impact on the mentee by increasing his/her confidence, self-esteem, skills development, and engagement in pro-social behaviour.

Kirkham and Ringelstein (2008) suggest that mentoring process success can be achieved in two ways. Firstly, by competency, developing deep learning and problem-solving skills, and increasing levels of self-esteem and motivation. Secondly, by formal recognition, this is gained from student participation, development of deep learning, and attributes such as communication, leadership, and interpersonal skills. These mentoring process features can also be applied to the study case.

The SPAM framework was adapted for this study based on the Programme's context which is discussed below. The adapted framework (see Figure 2) was then used to investigate the role and impact of project mentoring and the PM skills that are transferred through the Programme's project mentoring initiative.

2.2. Programme framework

The Graduate School of Technology Management (GSTM) at the University of Pretoria (UP) signed a Memorandum of Understanding (MOU) with PMI SA to carry out mutually beneficial activities to support and promote the art, science, and benefit of project management. Since 2018, PMI SA Chapter members have been teaching and mentoring tertiary students on the fundamentals of project management. The PMI provides all first year UP BCom students at the Mamelodi campus with Project Management Skills for Life training consisting of six one-hour training sessions over a six-week period. Each training session is followed by a short multiple-choice quiz to assess the students understanding of the material covered that week. Once this training is complete, the Programme team allocates a project mentor to each team after the mentors have gone through an induction.

Project mentoring is required for 5 months (June-October) to assist a team of 5 students to plan, execute/handover and write a report on their community project, and in so doing to successfully pass their second Business Management module. As a minimum every mentor interacts with his/her team for 2 hours a month for 5 months. The mentors guide their team on how to apply their project management skills, tools, knowledge, and techniques to deliver their community projects.

In 2020, 325 students, representing 65 groups benefited from the guidance and input of the project mentors. Five different SDG-aligned community project topics were chosen for the 2020 group. These community topics ranged from addressing food security by creating community vegetable gardens, reducing inequality by having a pop-up store for the homeless, to improving education by conceptualising, developing, producing, and handing over original ECD storybooks (written in a native language), toys and boardgames. Every team submits the following project artifacts for assessment: project scope statement, work breakdown structure (WBS), project schedule, responsibility assignment matrix (RAM), and a project close-out report.

Due to various Covid 19 restrictions that came into effect in April 2020 all project activities including the mentoring had to be done virtually with a geographically dispersed team, this challenged the execution and handover of the 2020 projects.

Based on the context provided above, the existing SPAM framework and the lessons learnt from coordinating the Programme since 2017 the framework in Figure 2 was developed and applied to the 2020 student cohort.

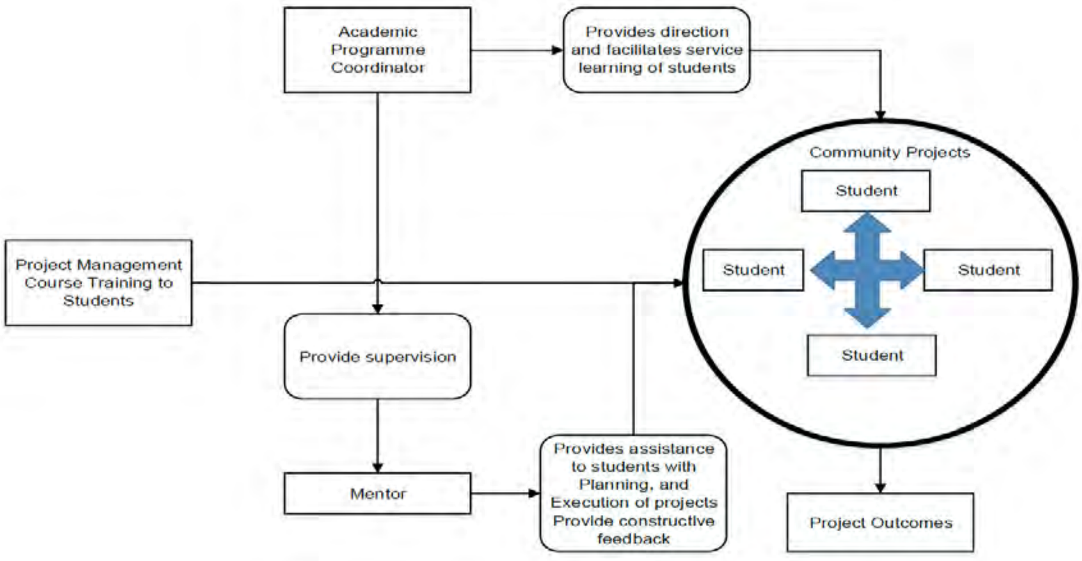

Figure 2. Programme framework

Figure 2 gives an overview of the project management interventions and the relationship between the Programme participants. The academic programme coordinator assists both the mentors and the students by giving direction and championing the vision for the whole Programme. The mentors provide assistance and guidance by ensuring that students are applying recommended project management processes, tools, and techniques in managing the outcomes of their projects. Within each team the students give themselves different roles and responsibilities (including the role of project manager) so that they learn the dynamics of working as a team. The students utilise their combined project management skills, knowledge, tools, and techniques to plan, manage and execute their team project.

2.2.1. The mentoring process

Agholor, Lleó de Nalda and Bárcena (2017) describe mentoring activities as actions that mentors and mentees perform during or within their mentoring relationship. A study by George and Mampilly (2012) revealed that socio-demographic characteristics and mentoring activities (teaching, providing a challenge, teaching politics, career help, sponsor, career counseling and trust) influenced the effectiveness of mentoring.

Apart from the role and impact that mentoring has in the Programme. It is also important to investigate which PM skills are transferred from the mentors to the mentees during the projects. Project management skills transfer is described as a process which consists of the project management knowledge extraction phase, project management knowledge recognition phase, practical knowledge transfer phase, and practical evaluation phase (Ioi *et al.*, 2012). It is assumed that mentors share their project management experiences and expertise with the group of students they are mentoring.

2.3. Research method

A qualitative research approach consisting of a phenomenological research design was chosen. A phenomenological design strategy was used because the participants had experienced phenomenon and we were interested in what they had experienced and how they experienced it (Creswell and Poth, 2016).

2.3.1. Participants

The study population consisted of 65 project management mentors and 325 students that participated in the 2020 community-based service projects. All the mentors and mentees were invited by email to participate in the study at the end of the 2020 Programme. Due to Covid 19 restrictions on travel (eg. students were at home without internet access), in some cases illness and especially the students apathy to participate in the study (once they had already completed their project and studies for the year), we had a very low number of participants. This to some extent affects the generalizability of the findings. We then decided to continue with the data collection process and encouraged mentors and mentees to participate until saturation of information was achieved (Guest, Namey and Chen, 2020). A sample size of 12 participants was determined to be adequate based on research done by Guest, Bunce and Johnson (2006). This research found that data saturation occurs within the first twelve interviews, although basic elements for meta themes are present as early as six interviews. Eight mentors and 12 mentees chose to participate in the study. A separate interview guide was developed for mentors and mentees. It consisted of some demographic questions, open-ended questions related to the role and impact of mentoring, the method and skills that were transferred during the project and the participant’s perception of the impact that mentoring had on the outcome of the 2020 community-based projects. The skills transfer questions referred to the soft and hard PM skills that were identified in the literature. The participants were encouraged to give open-ended descriptions of the types and ways in which skills were transferred between mentors and their mentees to allow for richer inductive thematic analysis.

2.3.2. Data collection and analysis

Data collection consisted of semi structured interviews that were conducted virtually due to the Covid 19 restrictions that were in place at that time in South Africa. All interviews were recorded and transcribed.

Inductive thematic content analysis was used to analyse the interview data and identify emerging themes (Easterby-Smith *et al.*, 2018). The analysis process as prescribed by Easterby-Smith *et al.* (2018) was followed:

1. Firstly, a set of criteria to transcribe information collected from the interview data based on the research interview questions for the study was conducted.
2. In the second step, the selected information was analysed with the aim that emerging themes will appear as relevant to answer the research questions of the study.
3. Once the main themes were identified, a table was used to summarize data from each participant’s interview. The table was used to identify the different relationships between and within the themes. Long statements coming from interview data were shortened and compressed into words or statements of what had been said.
4. After data had been summarised, it was linked to specific main points (Blumberg, Cooper and Schindler, 2014).
5. These main points were grouped into categories and analysed throughout the coding process to indicate different features, characteristics, roles, impact, method, and experience of the phenomena. Each point was linked to the theme and sub-theme it represented.

3. Results

Selected data are presented in this paper to answer the various research questions.

3.1. Q1: What is the role of project mentoring in the Mamelodi Community Student Projects?

One mentee participant perceived that the mentor’s role was that of a lecturer. Eight mentee participants stated that they understand the role of mentor as providing support and guidance to mentees to help them plan and execute their projects successfully. Four mentees indicated that their mentor kept the team accountable for the work they had to do, provided constructive feedback and suggested improvements to the project.

"Our mentor was vital in the planning and equipping us with the necessary skills to succeed". (Mentee 2)

"Our mentor oversaw the whole process, he checked to see if we were doing the right things at all times. This helped us to implement our project as best as we could". (Mentee 3)

This perception is supported Yob and Crawford (2012) who state that mentors are there to guide and assist students to achieve the outcomes that they have been set. Mentees mentioned that the mentor role was crucial, amongst others: as a sounding board during execution, sharing tacit PM knowledge, overseeing the process, helping the team to deliver the best possible project, maintaining team communication, helping the team cope with challenges and pressure.

Mentors also perceived their role in the project as important and making a positive contribution to the project team. Mentors stated that their role was to emphasise the importance of PM, and the positive impact the project would make in the community, to their teams. Two of the mentor participants mentioned that they offered additional support and assistance to their mentees (in the form of helpful examples and sharing past experiences) to improve the planning and implementation of their projects. This finding is supported by Savelsbergh, Havermans and Storm (2016) who state that line managers (in this case mentors) are important facilitators of the occurrence of learning experiences.

3.2. Q2: What project management skills are transferred between the mentor and the mentees in the Mamelodi Community Student Projects?

The inductive thematic analysis of the rich descriptive answers received from both groups of participants provided evidence for the transfer and development of various soft and hard PM skills in the Programme. The results indicate that communication, interpersonal, teamwork, resilience, leadership and problem solving skills were the main soft skills that were transferred and developed as a result of project mentoring. It was evident from the data that the mentors conveyed the importance of accountability, time management, a work ethic and organisation to the mentees. Due to Covid 19, mentors also assisted their teams to deal with the challenges of working in a virtual team, which developed their resilience.

"Perseverance in very difficult circumstances - none of the students had ever met each other because Of C-19 and were balancing the community project with other studies. Two students,in particular, showed great leadership and project management potential, and contributed to the overall team success". (Mentor 6)

Various hard PM skills were also transferred such as scheduling and budgeting skills as well as how to use various PM templates. Some mentors also exposed their mentees to tools to assist them to better plan and manage their projects such as Excel and Trello. This finding corroborates Fleming *et al.* (2015) who determined that experiential guidance via mentorship is an effective method to promote early career advancement and peer networking.

It was interesting to note that many mentees pointed out their mentor's leadership abilities, professionalism and PM confidence. This seems to have had an impact on the mentees as they mention that this gave them the confidence to complete their project. Mentees also stated that because they had to rotate between various roles in the project team such as project manager, administrator, subject matter expert and planner they developed leadership skills.

"My mentor taught me the importance of being an effective communicator as this can have either a positive or a negative effect on the planning and implementation of a project. He also placed great emphasis on ensuring that certain procedures are followed as this allows us to plan with greater foresight and encourages the thorough and efficient implementation of the project by the group". (Mentee 1)

This quotation is supported by Melling and Gurjee (2013) who describe working with others, improving confidence, support, and skills development of the mentee as a significant impact made by the mentor.

3.3. Q3: What is the impact of project mentoring on the perceived outcomes of the Mamelodi Community Student Projects?

10 of the 12 mentees indicated that project mentoring improved the outcome of their community based project.

"My overall impression is that the mentoring programme is very good and without it the quality of the community based service project wouldn't have been as high as it was.". (Mentee 2)

7 of the 8 mentors indicated that project mentoring contributed more towards improving the project results by developing the students' project management skills and assisting the students to execute their projects than what it increased the impact of the project deliverable. Mentor 6 stated that project mentoring is beneficial to the students that are interested and participate in the Programme. However, those that lack interest and don't participate do not gain any benefits from the mentoring.

Due to severe Covid 19 lockdowns that were implemented halfway through the 2020 Programme the feasibility of these project deliverables were compromised. South Africa was in a complete lockdown (limited to no movement allowed between provinces) at the time when the student teams had to handover their final project deliverables. Several teams (10) worked around these restrictions to be able to physically hand over their deliverables by couriering it or dropping it off on campus. As an example of student ingenuity Team L5 who were originally tasked with starting a community vegetable garden in Mamelodi. Decided that as a workaround to the Covid restrictions, they would rather grow the vegetables in their own gardens and then deliver the produce to ECD centres in Mamelodi, which they then did. The customer satisfaction feedback for these 10 teams 'met expectations' and in the case of 5 of these teams the community 'customers' said the project outcome 'exceeded their expectations' (Teams J1 and K4 street store projects, M4 ECD toy project, N2 ECD storybook project, L5 community vegetable garden project). For the remaining student teams a fallback plan had to be implemented, as several teams were unable to execute and/or handover the final deliverable, due to a lack of resources, geographic distance and isolation from other team members. The project deliverable for the remaining 55 teams was revised. The revised deliverable required these teams to submit a detailed project financial proposal which clarified the business case, the intended impact and all the going concerns of their team project to date. This revised deliverable was then assessed by the Programme staff and all 55 teams met expectations in this regard.

In addition to the expectation of a successful project deliverable, another project outcome was evidence of the mentors having made an impact on the students in terms of transferring and developing (soft and hard) PM skills, experiential learning and personal and/or career growth. In terms of this outcome the project mentoring was a success. Participants perceived the project mentoring initiative as positive from a personal point of view as well as it being beneficial to the community.

"The mentoring programme was extremely enjoyful and helpful for me as a learner. I got to understand more about project management from someone who is a professional in the field of project management". (Mentee 3)

"The mentoring program ensured that we as mentees develop knowledge about our project and some few skills like communication skills and I believe this has a huge impact or improvement on community-based service project outcomes". (Mentee 7)

"Having the mentorship programme was a boost and helped us to do a lot more than we would have done on our own". (Mentee 10)

"It is a good programme which uplifts the community" (Mentee 12)

"In between the mentor, mentee and the community service, my sincere impression is that all of these can have a lot of positive effects on students, such as helping them to develop skills, making contacts, and allowing them to improve the quality of life of others. It likewise allows students to learn more about their personal motivations, practice academic material and mentoring outside of the context of the classroom and testing, develop critical thinking skills While solving real-world problems, and to think about problems and social issues in new ways. This can include a better understanding of the value of teamwork, decision-making skills, development of leadership abilities, and the gain of practical skills. (Mentor 3)

"They had fun while learning about PM" (Mentor 7)

Five of the participants mentioned the transfer of skills and knowledge in managing projects as the way in which the mentor supported their career growth.

"Our mentor was very helpful, and I learned a lot from him. It was a good relationship which built me up as a future supply chain manager" (Mentee 12)

This notion is supported by Jyoti and Sharma (2015) who state that the experience, knowledge, and skills imparted by mentors on their mentees has a significant impact on their career development.

The most important benefits of a mentoring programme according to the participants was gaining practical experience and skills development.

"The support we received from our mentor was very helpful and insightful. My understanding of project management was increased because of the things I learned from our group mentor". (Mentee 3)

The findings endorse those of Melling and Gurjee (2013) who found that practical experience and the skills mentees develop are some of the benefits of an effective mentoring programme.

3.4. Disadvantages of group project mentoring

A lack of mentee commitment to the project was identified by three mentor participants. Other mentoring issues included a lack of time to plan and execute the project and difficulties in mentoring and assessing group activities and individual contributions virtually compared to a traditional face-to-face environment. One mentor mentioned that the mentees dependency on the mentor to help them execute their project activities as another disadvantage. Also a lack of face-to-face (in person) communication affected mentoring relationship success. The literature does not indicate if virtual mentoring affects mentoring relationship success, it is recommended that future studies be conducted on this topic.

4. Conclusions and Recommendations

Study findings suggest that project mentoring has a positive impact and role in the development of undergraduate students' project management skills. It also improves the outcomes of the Mamelodi community-based service projects. Study findings reveal that the role of a project mentor is very important as it encompasses the following tasks which benefit the student team: assist, support, guide, give constructive feedback, suggest improvements, keep accountable, share PM knowledge and experiences, lead/oversee, help, maintain team communication, encourage and teach. Project mentoring is especially important to enable students to apply their knowledge to real-world projects where the educator's capacity to support and guide a large group of students is constrained. Moreover, the external perspective and insight that the industry-focused project mentors bring to the table expands the student teams' view of: the project objectives, the relevance and application of PM knowledge and skills to the project and how the service-based project experience may impact their career paths in future.

Based on inductive thematic and frequency analysis the study found that the project mentors are instrumental in transferring the following project management skills to their mentees. Project management soft skills such as communication, interpersonal, teamwork, resilience, leadership, problem solving, accountability, time management, work ethic and organisation are transferred between the mentors and their mentees. The 2020 mentors also guided their mentees on how to work effectively as a virtual team. Both groups of participants (mentors and mentees) felt that the Programme increased the transfer and development of PM soft skills most. The hard project management skills of scheduling, budgeting, using PM templates and tools were also transferred from the mentors to the mentees.

Finally, project mentoring and experiential learning impacts the mentees career development, project management skills and knowledge, confidence, and ability to work with others. There is also a significant impact on the community due to the SDG focus that is inherent in the Programme's projects.

The study results reveal that the Programme is a good initiative to promote community-based service projects and create a platform for students to interact and learn from practising and knowledgeable project practitioners and build on their ready-for-work skills. The mentors benefitted from the Programme through personal growth, giving back and by gaining professional development units for the time they spent teaching and mentoring the students.

The proposed project management mentoring programme framework (figure 2) could be used by educational institutions and other training organisations to improve the transfer of PM skills to undergraduate and postgraduate students.

A limitation of the study was that not all the student teams were able to execute and hand over their project deliverables, due to Covid 19. The mentoring programme had to be carried out virtually which created communication challenges between the parties. The Covid-19 pandemic did not allow for face-to-face interviews with participants. This limited our ability to probe and verify participants' responses.

It is recommended that future studies be conducted on the impact of virtual mentoring on the project outcome/result. Some of the participants confused mentoring with teaching. It is recommended that further research be conducted to determine the similarities and differences between these terms, in the context of service learning.

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Digital Tools for Career Path Management Support: Project Decomposition and Impact Analysis

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Abstract:

Business and policy sector are changing its human resources (HR) policies globally, changing ways in policies and practices related to employee management and employer branding. The process of career path management was mostly manual work, often carried by individuals, professional agencies or HR officer in organization. In today's challenging labour and educational market environment, this process is inefficient and slow with and often limited in success. In this paper data science-based decision support system for career path management support will be presented including components, project management challenges and impact analysis. System was built on national level in Croatia to support labour and education market stakeholders and ecosystem participants as advisory tool. Using data provided by system, parents, EDU institutions, policy makers and individuals can have deep and comprehensive overview on market dynamics and mechanics. In its essence this project is IT project but with increased pressure on project manager because it affects people with oscillations and inequality in their competences and motivations therefore in constant need for education of all participants and communication in and out of project and user groups. Paper will present characteristics of data science project with focus on predictions and decision-making techniques relevant for project success. Special focus will be given to team communication and project results impact analysis throughout the project. In this form paper can be great resource for future candidates to certify IPMA project management certificate in fields of computing and data science.

Keywords: *digital tools for career path management support; project decomposition; impact analysis; data science in project management*

1. Introduction

Data Science is mainstream, and many organizations in the most competitive markets are beating the competition by being more data-driven. An increasing number of different projects can involve an involve aspects of data science. This creates a problem. Without standardised methodologies for managing data science projects, teams often rely on ad hoc practices that are not repeatable, not sustainable, and unorganized. Such teams suffer from low project maturity without continuous improvements, well-defined processes and check-points, or frequent feedback (Saltz, 2015). Most data science projects are time fixed ventures with limited budget. While it's healthy that data science projects have some loose "free-time" due to their scientific nature, the fact that resources (time, money or people) are limited, justifies that data science projects have to be planned carefully. In the end, you want to make stakeholders happy and good planning sets expectations and controls the project execution. This is especially relevant for freelance consulting where drifts from the original plan may be crucial. Financial incentives must be aligned regarding the project implementation and any over-budget or incomplete projects normally spawn from bad planning. While it is true that data science projects have a likelihood of failing, the reasons for that failure should fall back on the lack of experience in managing complex, fast-changing, data environment, not on a lack of planning.

1.1. Data science: where practice meets science

Without the expertise of professionals who turn cutting-edge technology into actionable insights, big data is nothing. Today, more and more organizations are opening up their doors to big data and unlocking its power, increasing the value of a data scientist who knows how to tease actionable insights out of gigabytes of data. It is becoming clear by the day that there is enormous value in data processing and analysis and that is where a data scientist steps into the spotlight. Executives have heard of how data science is a sexy industry, and how data scientists are like modern-day superheroes, but most are still unaware of the value a data scientist holds in an organization (Vamsinellutla, 2018).

Project management should take advantage of the data driven world. Every business activity benefit significantly from the synergy of different professional disciplines. Take the first step and open yourself up to questioning; this will give you a greater sense of data team motivations and interest in the project. At the same time, the team can gain invaluable insight to improve the quality of its data products. Do not end any data-driven evaluation exercise without thanking the team for the effort. At the end of the day, if you have the fortune to work with a data team that is striving to improve project results, that's a major win. The process of making data-driven decisions has always been a part of the project management profession, and it has been gaining greater attention as the market introduces more products, and the data-handling techniques become cheaper and more comfortable to use. Every profession evolves with new practices and points of view, so we should all take advantage of industry and occupational trends to leverage the tools and expertise with our core professional values. Managing projects means making decisions (Bernardo, 2022). This process can be supported by data mining and machine learning techniques, based on selection and analysis of project data in order to make better decisions and resolve some typical project problems. Data plays a significant role in any organization. Using analytics, managers and executives can watch for early signs of slippages in terms of budgets, costs, and timelines and take corrective action. Analytics also helps managers capture the rate of work, so they can easily predict whether the project will be completed on time. Managers can use a burn-down chart, for instance, which is a graphical representation of work left to do over time. Moreover, deep and insightful analytics can help you improve resource utilization and better forecast revenue and costs. With analytics, organizations can take a broader view and combine unrelated data streams to offer deep insights into projections and early warning signs in complex projects. This role can be taken by Program Management Office (PMO) in an organization (Datamine, 2022).

Gartner says, 80% of today’s Project Management tasks will be eliminated by 2030 as Artificial Intelligence takes over. Artificial Intelligence will not be replacing anyone’s jobs just yet, however, AI will help make better decisions leading to improving the chances of delivering projects on time and on budget (Gartner, 2017)(Gartner, 2019). Traditional project management functions like planning, data collection, tracking, and reporting will be taken over by machine learning algorithms. The role of the project manager will gradually evolve into one that is more strategic as opposed to current tactical role. AI shall be a work augmentation tool, not a human replacement and AI cannot manage a project, so project manager's tedious status reports and messy resource scheduling could be greatly improved with AI, machine learning and robotics process automation (RPA), but it can't gather requirements or get stakeholder buy-in. However, organizations will have to adopt the use of AI in projects and hence they have to merge the power of humans with that of machines learning for better managing their critical projects. With applications of artificial intelligence already disrupting industries ranging from finance to healthcare, technical project managers have to grasp this opportunity and learn how AI project management is distinct and how they can best prepare for the changing landscape for use of AI in project management. AI and machine learning will help in enabling a fully digital program management office (PMO) in future. Data analytics techniques can enable project managers to use various analytical reports and drill-down charts to break down complex project data and predict their behaviour and outcomes in real-time. Project managers can use this predictive information to make better decisions and keep projects on schedule and budget. A data-driven analytics approach enables project teams to analyse the defined data to understand specific patterns and trends. Executives can use this analysis to determine how projects and resources perform and what strategic decisions they can take to improve the success rate. A report by global management consulting company McKinsey, discovered that US $66 billion was "lost" across 5.000 separate projects. This was due to them exceeding their lifecycle, poor planning, and the wasteful expenditure on the wrong kind of talent. Data plays a significant role in any organization. Using analytics, managers and executives can watch for early signs of slippage in terms of budgets, costs, and timelines and take proactive action. Analytics also helps managers capture the rate of work, so they can easily predict whether the project will be completed on time. Managers can use a burn-down chart, for instance, which is a graphical representation of work left to do over time. Moreover, deep and insightful analytics can help you improve resource utilization and better forecast revenue and costs. With analytics, organizations can take a broader view and combine unrelated data streams to offer deep insights into projections and early warning signs in complex projects (Canuma, 2022) (Crowston et all, 2019).

2. Materials and methods

Main responsibility of a data scientist to extends from manage projects from top to bottom, onto learning some frameworks will definitely help in understanding certain project decisions and participate constructively in steering the project to success. Another point is that learning some project management skills and frameworks will help one step up career to senior positions as these skills are even more relevant as you increase your responsibility. When planning complex project and looking to support project management with digital technologies, one of the key steps is to determine digital maturity of environment in which project will be implemented. Such tools can but doesn't have to be very complex, however their point is to increase awareness and project management carefulness and introduce as many middle steps as needed to assure adequate level of understanding from all key stakeholders and (in ideal) participants (Misra, 2021).

Figure 1. Digital maturity assessment tool (source: Algebra University College)

Data science failure rates are sobering: 85% of big data projects fail (Gartner, 2017); 87% of data science projects never make it to production (VentureBeat, 2019); "Through 2022, only 20% of analytic insights will deliver business outcomes" (Gartner, 2019). There are many reasons why data science projects are different, however we will tackle mist important keypoints are present overview of "from data to business value" path. One of the important points to consider is that data means transparency. Client needs to be aware that insights don't can be very intriguing for organisation (for example if dealing with fraud analytics or other big data utilization techniques). Among most important "failures" and reason why it is not easy to find big success stories among industry landscape, is that one organization realize key insights they often decide to hide it from public. Either because such insight can bring competitive advantage to company or because such insight deeply jeopardizes common practices that are "in place" in the company. Next, point is that technology is often valued more than the outcome. As data people, we sit firmly in the "tech is cool" boat, but it's easy to get swept up by new and exciting technology. It's also common for businesses to over-engineer solutions to problems that would get more benefit from a simpler solution (Martinez et all, 2021). In data projects, that can often look like experimenting with new technologies or methods that don't solve the problem, adding even more intricacies to what's probably an already complex feat.

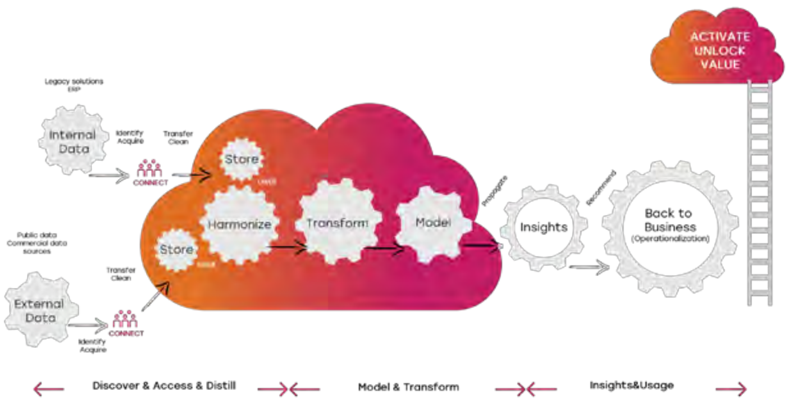

Figure 2. Data science project, technical elements decomposition (source: Algebra University College)

Finally, our last point is challenge of relying on one internal set of eyes. Gone are the days of the lone-wolf data scientist executing a complete data analytics project alone.

However, while data projects require the right mix of talent across teams within an organisation, businesses all too often hand over projects to one internal person or team, which can be risky for several reasons, they might leave the company, have conflicting priorities (prolonging timeframes for delivery) or unintentionally do things incorrectly. Of course, some of those can be mitigated with risk management framework which help to plan for uncertainty and better build probabilities around events that can sabotage your data science project. Identifying and assessing these risks is nice way to create escape routes and plans to avoid chaos. Each phase in the project involves risk, for data science projects the most common risks revolve around resources and data (Saltz, 2021). Like in any other project, questions like: what happens if one of my data scientists leave the team (due to sickness, voluntary leave, etc.); what happens if we can't work with the data sources we need to train our model; is there a regulatory risk involving any of the data contained in my data sources; can arise, but when dealing with data, their implications on project success is much more crucial. To be able to understand most important phases and project situations, we have to go back to general skills: constant communication and valuable feedback. Why is this important for data scientists? Data scientists need to be able to communicate their results in a clear manner and translate the complexity of data science models for business stakeholders. Particularly, data scientists should avoid being an "ivory tower engineer", building good communication skills is a good step to build more emphatic relationships with colleagues and stakeholders (Paulk et all, 1993)(Mayur&Joshi, 2021). Constant communication and clear feedback is a really special skill that can be used throughout several phases of the project include: communicating model improvements; asking for stakeholders feedback; incorporating new information into project development; giving feedback to other developers about their code. All-in-all, constant communication is a way to prevent shielding stakeholders from the project development, improving the likelihood of project success (Crowston et all, 2019)(Ebner et all, 2014).

2.1. Setting the stage: project importance

The process of modernization and reform of the qualification system in the Republic of Croatia is carried out through the Croatian Qualifications Framework (HKO), which establishes a mechanism for recognizing discrepancies between supply and demand for work at the level of competences. The HKO ensures examination of needs based on analytical foundations, clarity, access to acquisition, grounded acquisition, possibility and quality of qualifications and connection of qualification levels in the Republic of Croatia with EQF (European Qualifications Framework for Lifelong Learning) and QF-EHEA (Qualifications Framework for the European Higher Education Area) and indirectly with the qualification levels of qualification frameworks in other countries. The process of adapting the education system to the needs of the labor market in the process of establishing the Croatian qualification framework begins with the creation of occupational standards. Proponents of occupational standards based on the Act on the Croatian Qualification Framework can be all legal or natural persons and state administration bodies that have a justified interest in doing so. The occupational standard is a document in which the key tasks and competencies required for a specific occupation are clearly stated, as well as the sets of competencies that will be linked to the sets of learning outcomes in the qualification standard. For the creation of occupational standards, it is necessary to provide professional bases, that is, analytical tools, which will serve as a starting point for the proponents in the creation of occupational standards. The creation of tools is, on the basis of the aforementioned Act, the responsibility of the Ministry of Labor and the Pension System. The methodology for the creation and interpretation of the sector profile defines the creation procedure and the method of interpretation of the sector profile for the purposes of creating proposals for occupational standards. Sector profiles are documents that outline the state of a certain sector at a certain point in time, and show the most important elements within each sector. In addition to the Occupational Standards Survey, which is used in the creation of occupational standards, the sector profile serves to assess the offer and serve as an aid in making personal decisions when continuing education and choosing a career path. The registration of occupational standards in the HKO Register (Sub-register of occupational standards) will enable the connection of occupational standards and qualification standards, as well as the updating of the National Classification of Occupations (NKZ). The national classification of occupations, as a national standard of official statistics, ensures unequivocal communication of providers, holders and users of data, primarily in the official statistics of the Republic of Croatia, but also in employment mediation, in the education system, in the development and management of human resources, in science and other researches. In order to achieve international comparability of the data of official statistics on occupations, the existing National Classification of Occupations is harmonized with the international statistical standard of occupations ISCO-08, which is part of the European Classification of Skills, Competences, Qualifications and Occupations (ESCO): ESCO is a multilingual classification that uses standardized terminology on all languages of the European Union. The purpose of ESCO is to facilitate the exchange of data on supply and demand in the labour market at the international level and to facilitate dialogue between the labour market and education.

2.2. Digital perspective of the project

Project can best be described through several goals, the most important of which is the establishment/upgrading of a system for advanced monitoring of the labour market and education, which is also the fundamental mission of the Client, through the selection of technology, the establishment of data exchange procedures between public institutions that own that data, the automation of exchange procedures, formation of a data lake, creation of interactive visualizations for use by the Client and the authorized public, which is one of the key tools that enables the fulfilment of the organization's mission and vision. Project identified the development of data management technologies, automated exchange, secure work with private data and development of public infrastructure (Centre for shared services of the Republic of Croatia, CDU) as an opportunity to influence the organization's strategy and incorporated/used in project activities. When building the system, project team chose and used methods, technologies and analytical techniques, as well as the chosen way of publishing reports that follows all modern elements for scope management (scaling) and minimal requirements for technical interventions, providing the basis for continuous support of project justification. When establishing the project tasks, project team combined related and important activities and associated deliveries, which, with an acceptable additional expenditure of resources, were combined as related. In particular, we are referring here to the establishment of the basis for the register and data exchange of regulated professions, the creation of a methodology for the formation of a new National Classification of Occupations, the establishment of the basis for the formation of a new NKZ and the education of users in the process on how to use the tool. Strategic support was extremely important for the project, considering that it was an innovation on multiple levels, a challenge for acceptance, but also a critical need for the future activities of a modern organization. At the strategic level, project team presented domain and technical knowledge, demonstrated an understanding of the broader context, the ability to apply knowledge in a way that had to ensure acceptance at a higher level of efficiency than earlier solutions, presented the ability to analyse and synthesize according to the levels of data granulation, and by preparing and presenting insights as a basis for successful evaluation and finally ensured acceptance at all levels of users and (internationally) interested public. Strategically, as a manager, project team provided and ensured the provision of much more to the organization than just the delivery of the set results, and enabled a number of related strategically important benefits that resulted from specific combinations of knowledge by setting work rules that are recognized beyond the framework of the project owner and will be used in future work. With the project, project team also enabled the client to bridge the multi-year gap in communication between the bodies that were supposed to participate in the activities and to set a new point in time that actively returns the project owner to the timeline of the activities of harmonizing the organization's work with modern technologies and enables quality communication within the EU with an additional important positioning of the organization as a change leader and innovator in tools for advanced analysis of the labour market.

Presented project and platform is unique in many ways therefore important on national and EU level, among other key point we can name: the first such service of any state body on the CDU integrated with the NIAS system; the first and largest national service of this scope/type and modern technological platform aimed at policy and industry experts; Service with an extremely high degree of inter-operability, data automation and autonomy of users who do not require IT support in their work; unique in the EU, the first to enable interactive monitoring of the transition to the labor market; the first service of its kind that integrated ESCO classification data into operational reports and linked them with data in the Republic of Croatia; system integrate data lake with over 300,000,000 records and more than 300 reporting segments organized into 10 groups. Project is part of funding initiative "Implementation of HKO and development of tools in connecting education and the labour market" worth more than 3.0 EUR million.

3. Results

3.1. Discover, access and distil (DAD)

The project team, both on the side of the executor and on the side of the client (but to a lesser extent), required the adjustment of the energies of the members in relationships and went through various stages of engagement of the team members. It was necessary to harmonize expectations and ensure continuous monitoring of work and management of the professional motivations of individuals. During the project, project team was also faced with the fact that the client's team went through the challenges of departures of technical and administrative members, the introduction of additional external consultants and the always demanding change of owner, intensified with the outbreak of the pandemic, which affected the availability of stakeholders to work on to the project, testing solutions and generally to communication with external interested parties. Focusing on the vision of the project, the importance of project activities that goes beyond individual members and, in parts, the organization of the client itself, reinforced by my vision as the project manager, which Project team have presented the project on several occasions in various countries (Serbia, Belgium, Slovenia) and in Croatia through interest networks, and in order to present individual parts and finally the whole to experts of various types and to provide additional value through building and moderating relationships and strengthening the reputation of the client's team, my team, the institutions to which the experts belong, and the national capacity to deal with the project topic.

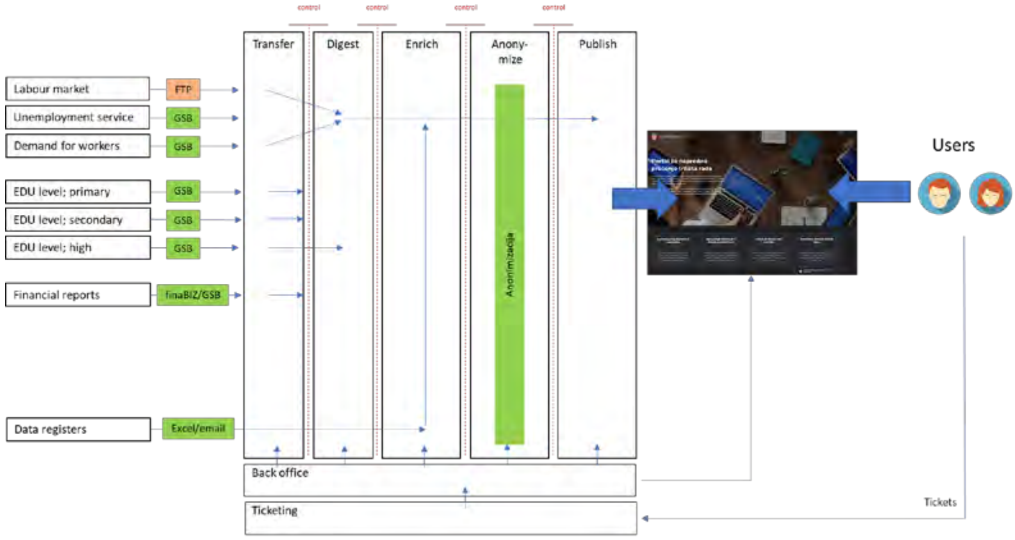

Figure 3. Data management and automatization (source: project documentation)

The previously mentioned diversity of team members, further reinforced by the challenges of goals that were partially or unsuccessfully addressed by the client in previous projects, required us to work actively and actively on proactively helping team members to adopt and apply different knowledge and ensure a synergistic effect. On several occasions during the project, it was necessary for project team to additionally direct especially external stakeholders, and in order to ensure that an adequate but very demanding infrastructure was provided, to combine technical and domain knowledge, and to ensure the dynamics of work and the implementation of activities with the aim of improving the work of individuals and thus teams involved and the process. As a experienced team, we repeatedly showed a strong commitment to disseminate and share technical knowledge needed to perform the most sensitive parts of the project, combining the vision into technical possibilities and limitations into insights and final service. Also, on several occasions, especially during the introduction of systems, working techniques with ethically sensitive insights, and after the change of the sponsor, by communicating outside the circle of project members and using influence, project team ensured through our own actions a space for quality communication in sensitive, one could say challenging conditions that were could harm the project. During the whole process, and especially during the creation of the principles of the formation of a new national classification of occupations, the education of over 250 people to work with the data bases that we personally designed and created, and the work on visualization panels and designing the interaction that users will apply, making and implementing decisions was for us subject to internal and external review and validation at multiple content and organizational levels. Project team directed the project in such a way that it would be possible for individuals to get involved beyond the project area itself, and to acquire additional technical knowledge and join the mentoring program as candidate participants in order to acquire and further apply the knowledge resulting from project activities and results. Project team also aspired to learn new knowledge, especially domain knowledge and those related to the responsibilities of policy makers in the labour market. As we relied on a number of important external stakeholders through the project (we didn’t explicitly mention it, but it is common risk to be considered and mitigated), we can recognize the impact of the project on the wider environment, but also the recognition of the contribution of the project that we led in other teams outside the organization and through the delegation of tasks and responsibilities and the monitoring of results through the validation of deliveries and interaction with the users of the results. This part specifically refers to teamwork and the creation of a culture of teamwork, both in the project team and the team's communication with related teams in other projects that use the results of this project. Through previous experience, we worked on working buy-in strategies to motivate related stakeholders to notice and adequately value the project team's project efforts and the use of these facts to promote team synergy.

3.2. Project outcomes

The initial plan of the scope of deliveries was defined by the project assignment, but in the assignment itself, a number of elements are described very superficially, or rather at the concept level. The subject of procurement is defined as services for updating the national classification of occupations, creating a computer program/application for regulated professions, upgrading the analytical platform and publishing data and improving the data exchange system according to the system of advanced monitoring of the labour market, improving the process and creating registers in the area of regulated professions, creating registers / application of individual occupations of the NKZ, and education and support for proponents of occupational standards when using analytical bases for the creation of occupational standards. The scope is divided into three basic groups of activities with five subgroups and seven basic and two additional items. Subgroups represented work packages and contained significantly different types of activities that are interconnected as a whole. When planning the execution, Team directed the scope towards the establishment of an analysis platform to which all related services of the client would later be connected, therefore it must be scaled and prepared with a high degree of scalability, availability and interoperability. We described the scope as cooperation on making recommendations for upgrading the technological platform, launching an analytical platform, analysing content for data exchange (list and description of data, method and frequency of delivery, responsible persons for delivery for each source), in cooperation with the client's team, establishing storage mechanisms data to the analytical platform and their automation to the extent possible (ultimate goal fully automated exchange), consulting on procedures for maintaining the analytical platform (technical infrastructure/specify separately from other services). Defining additional types and characteristics of input data for automating the process of receiving data from the Croatian Employment Service (HZ) and the Croatian Pension Insurance Fund (HZMO) on a monthly basis and the Ministry of Science and Education (MZO) and the State Bureau of Statistics (CBS) depending on their periodicity and according to the needs of the Client. Expansion of HR/EU data sources; structured (EURES, ESCO and others) and unstructured (CEDEFOP, employment portals and others) and defining the form/shape/variables of input data for automating the receiving process and their integration into the analytical platform in cooperation with the Client's team. Creation of a model for analysis that includes: analysis of received data, analysis of data correctness, identification of links between data, definition of keys on entities, adjustment of data for the purpose of improved display model, creation of procedures and functions for data selection, programming of system refinement based on created procedures and functions , upgrading of data display algorithms, adaptation of obtained algorithms and displays for export, matching of data with the possibility of obtaining a trend display according to the most important parameters of the database, and consulting related to the connection of available sources with relevant EU sources. Transformation of data for the purposes of visualization in accordance with current needs, which includes: analysis of received data, analysis of data correctness, identification of links between data, definition of keys on entities, adaptation of data for the purpose of the existing display model, creation of procedures and functions for data selection, system programming based on created procedure and function, adjustment of obtained algorithms and display for export, front-end visualization, i.e. starting the visualization system. In addition, we included in the scope the related activities of preparing the methodological basis for the creation of occupational standards and conducting trainings to support the use of advanced analytical bases for proponents of occupational standards in the process of creating occupational standards and the improvement of NKZ, i.e. processes in the area of regulated professions.

3.3. Project results

For the purposes of implementing the project, we created an accompanying/conceptual sketch that we refined and enriched over time in relation to the deliveries and flow. The initial idea and way of working for the main component of the project is presented in the following sketch. Key results are defined as (Moyle&Jorge, 2001):

1. Set rules for regular data exchange between sources (institutions, registries)
2. Establish an analytical system in which data from sources will be collected automatically
3. Form data connection and transfer control rules
4. Ensure the possibility of scaling the system with new data or additionally with historical data over time
5. Use of advanced analytical methods of data transformation with the aim of finding important characteristics and preparing for data visualization/publication
6. Data visualization
7. Education of users about the use of the system for specific needs (e.g. creation of specific reports for a particular area of the labour market)
8. Integration with EU-level labour market monitoring initiatives (registers, monitoring)
9. Analysis of usefulness and collection of other data important for the labour market from open sources and their integration into the analytical system (long term)
10. Publication of public data to users (public or authorized) (long-term)

For the needs of various interest groups, team created and held several presentations of parts of the system, which in the technical architecture part consists of over 300 visualization segments. We used the most modern technologies for data preparation, containerization, visualization and serving for data display. We documented the data enrichment procedures and developed the system with a vision of further improvements and expansion of data from other sources. In this context, it is possible to point out that the system is ready to accept NKZ10 with individual occupations and use it in parallel with NKZ98 during parallel use, and that the system already uses links according to the ESCO classification (currently in version ESCO 1.05). Data exchanged with the Croatian Employment Service (HZZ), the Croatian Pension Insurance Institute (HZMO), the State Statistical Office (DZS) and publicly available data from the Ministry of Science (MZO) for higher education are used for the visualizations. Through the project, protocols for the exchange and expansion of the data set that is exchanged were prepared with: HZZ, HZMO, DZS, FINA, MZO (secondary and higher education), after which they become candidates to expand the portal.

The selection of reports are grouped on the left side of the portal. The reports are grouped according to content in groups: (i) labour force sfacts, (ii) employment, (iii) unemployment, (iv) overview by county, (v) overview of the HKO sector, (vi) overview by profession, (vii) long-term trends, (viii) education sector (primary, secondary and higher education) statstics, (ix) employers and (x) labor market analysis through the ECSO skills pillar and (xi) career paths. On the right side of the portal are technical functions for interoperability: (i) export data as an image, (ii) export to PDF, (iii) source directly to PowerPoint, (iv) export tables, (v) display micro data. In addition to them, there are also management functions: (vi) cancelling all filters, (vii) refreshing data and (viii) turning on full-screen display. The assessment is that communication through work with the system is a very good way of affirmation.

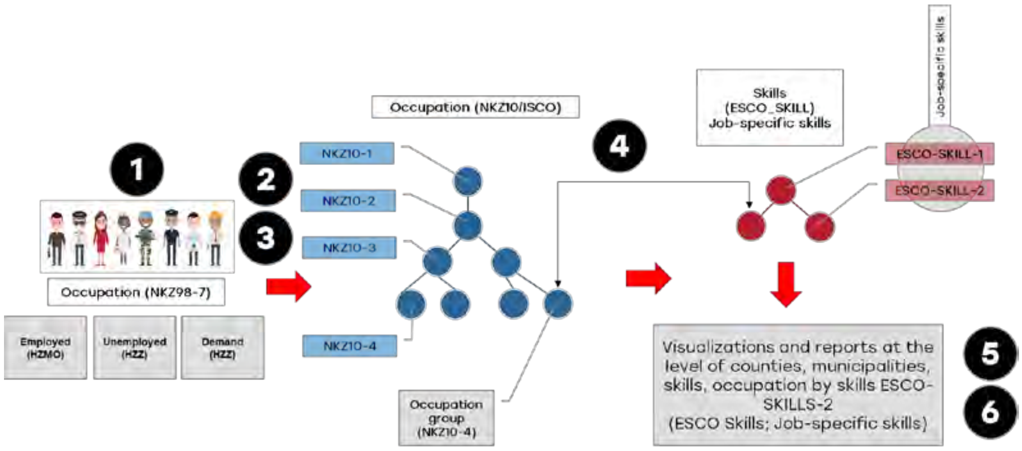

Figure 4. Project management document draft, occupations and skills (source: project documentation)

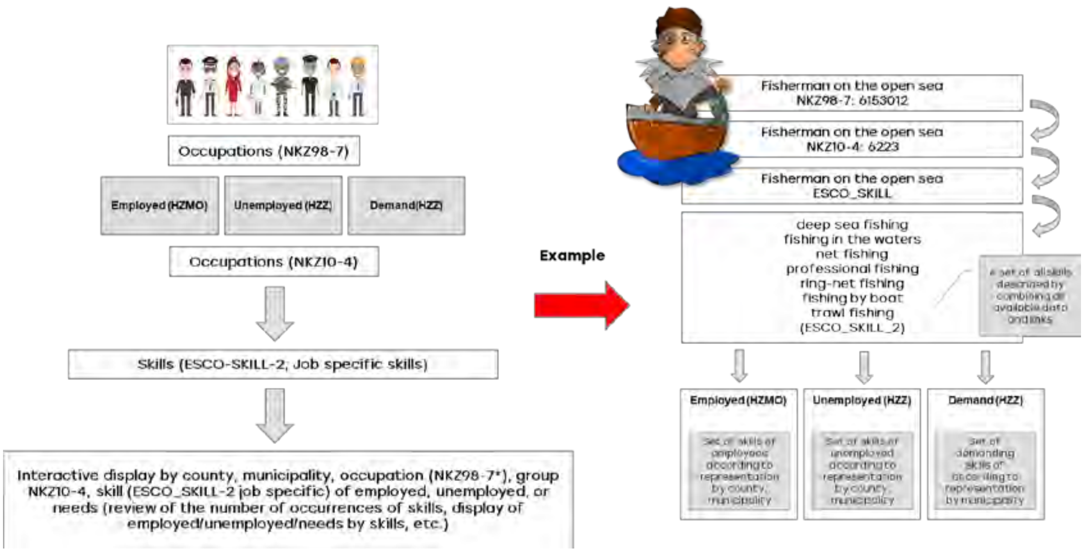

Figure 5. Project management document draft, skill analysis (source: project documentation)

Additionally, we developed usage scenarios for the affirmation project strategy team, such as mentioned in the example below and in the attachments in order to bring closer the way of using the portal in solving business challenges to a group of users with an emphasis on strategic management.

The project was designed by the client as a basis for further, long-term development and has the power to change the position of the client's organization at the national and EU level. We developed it using the most modern technology, and the best experts in the country participated in it from the domain side. We documented the system in both methodological and technical terms, and the procedures that were used are methodologically repeatable and with a clear emphasis on the simplicity of the user interface and interoperability and work with data. We paid special attention to the intuitiveness of display and use, reducing the need for technical support to a minimum during use (the user can use, view and export data according to the authorization level) and creating value for the client. Menus are accessed simply by moving the pointer to the left or right side of the portal.

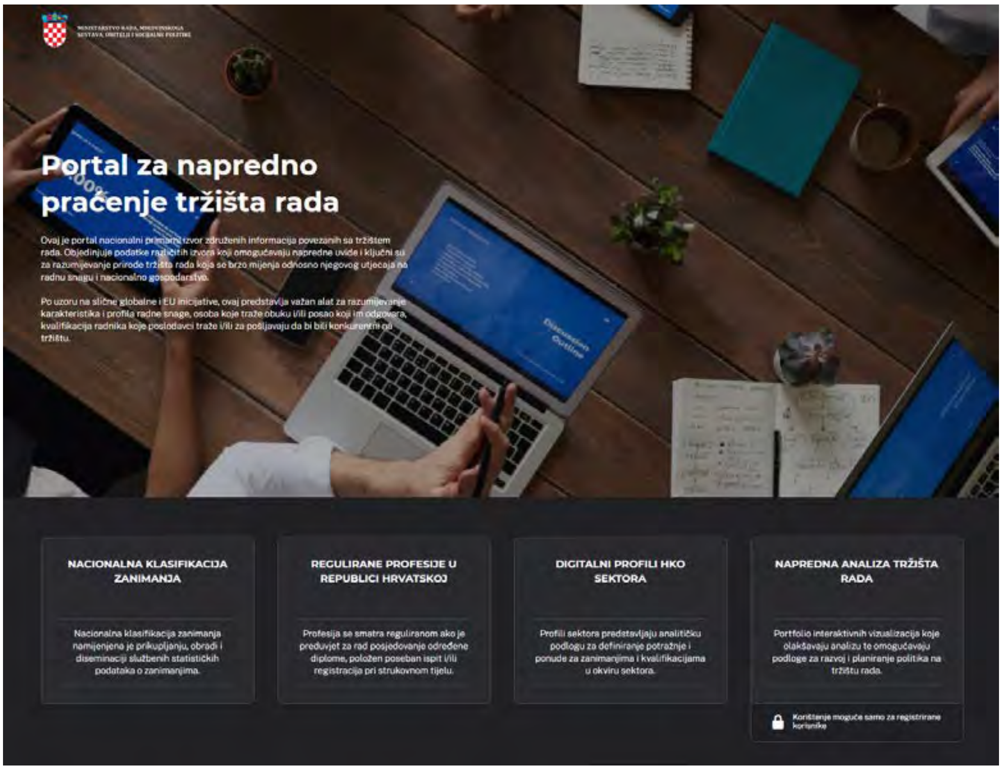

Figure 6. Portal front page (https://trzisterada.gov.hr/)

This approach makes it possible to combine official statistics and large data sets to support policy makers in the political issue facing Europe and the Republic of Croatia as part of it. To remain relevant, official statistics must evolve and integrate new data sources into their production. In a concrete example, the project demonstrated how big data can be used to supplement official statistics. In a fast-growing and changing world, the business of all sectors and industries is exposed to digital transformation, digitization and digital changes more than ever. Motivators, i.e. drivers of change, can often be grouped into several basic categories: technological evolution, various crises such as political instability or change, revision of business processes, changes in customer habits, pressure from competitors, acquisitions, mergers and organizational restructuring. Changes in business include methods that redirect and redefine the use of resources, business processes, budget allocations and other business models that significantly affect the organization/company itself. Therefore, it is not surprising how much fear these changes can cause in the employees of the organization. The methods and approaches used in the project, together with the documentation, represent the basis for further improvement of the strategy for managing change and transformation. Project team, from the very beginning of the project, evaluated the client's organization's adaptability to adopt identifying points that needed careful attention and special care. For the successful implementation of the project in its defined scope, and its completion in the stipulated time, it was necessary for us to form a relationship and a joint team in which the experts of the client and the tenderer participated. The goal of organizing the project was to provide a framework according to which all types of activities can be planned, executed, monitored and completed in a consistent manner. In the initial phase of the project life cycle, We defined and analysed the problem and presented some possible solutions by documenting the costs, benefits, risks and other characteristics of each solution. Based on the analysis, we chose a solution that could be successful and started the parts of the project activities that we had planned down to the smallest detail. we formulated visions and strategies of project parts, defined goals, modelled and planned financial costs and benefits, and analysed key resources. After the detailed planning of the project, we moved to the phase in which the elements of the project are implemented. This is the most sensitive part of the project, in which the team is activated, everything is organized, decisions are made, problems and conflicts are resolved, and all necessary activities are contracted. In the implementation phase, project team needed to manage time, costs, risk, acceptable outcomes and communication between project participants. In the final phase of the project life cycle, which is no less important than the previous two phases, we framed all the results in order to evaluate the success of the project. Given that every project has a social dimension, project team also analysed the interaction of the project with the environment, because it is extremely important for project management to find the environment, i.e. internal (factors within the company itself) and/or external factors (factors outside the company, e.g. users, researchers, public, socio-cultural and political environment) that are essential for the success of the project. While internal factors can be influenced by the company, external factors can be influenced partially or not at all.

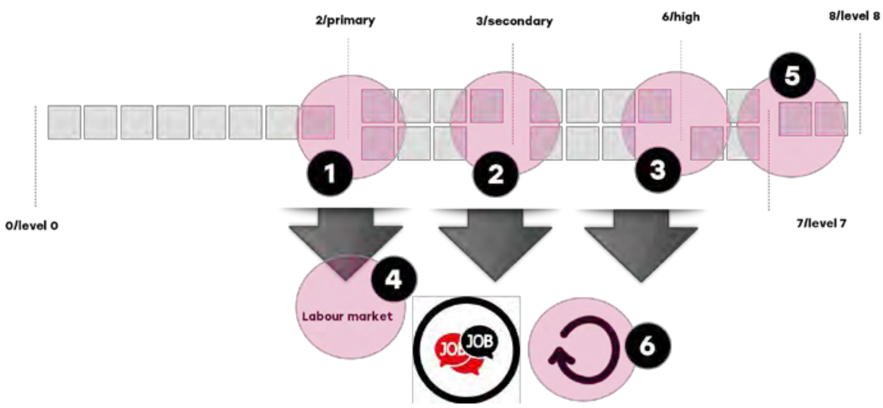

Figure 6. Career management using big data; concept draft (source: project documentation)

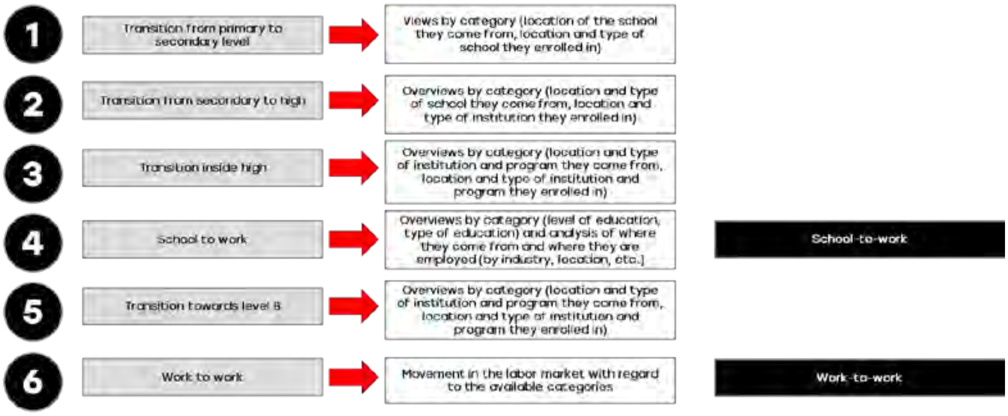

Figure 7. Career management using big data; preparation of insights (source: project documentation)

During the definition phase of the settings, we presented at the workshops ways of computerizing the customer's business processes. We defined the basic parameters for setting up the system, and defined the data conversion strategy and data flow between components. During this phase, we worked intensively with key users who know the business processes and needs of the client. At the end of this phase, key users have accepted the design of each new component. Additionally, during this phase we defined and documented the interfaces that needed to be developed and implemented as part of the project. We set the accepted system design during the construction phase. We set the parameters of the components and developed the prerequisites for the necessary system and interface adjustments. This was followed by the transition of the components to the test environment, and the maintenance of key user trainings in the test environment together with the delivery of user instructions. In this phase, we prepared work scenarios of the existing work/system for conversion to the new system according to the specification that was validated by the customer's expert. This refers to key work processes according to target groups of users. We spent the testing of the system working with key users who were trained. Testing was conducted based on agreed test scenarios designed and delivered by us, which were adopted by key users along with example documents representing the results of the testing. Testing consisted of testing individual system modules, testing data conversion from the old to the new system, and ultimately an integration test covering the entire business processes. This phase ended with a record of system acceptance by key users.

4. Conclusions

In the future, business performance will not be the only measure of driving operations. Instead, Data Science is going to take centre stage. We are already experiencing how businesses are taking data analysis to the next level so the time is not far when it will become a holistic approach. Businesses will begin using data dcience in various operations, which will obviously include project management (Hotz&Saltz, 2018). Data science also makes natural sense for the field of project management. A lot of factors are involved in the success of a particular project. Analysing data is a strategic approach to determine goals, achieve them, and overcome any gaps. Project management, just like data science, is not simple math. For varying business industries, the needs of a project management department can differ. Nature of certain projects can be quite complex as compared to some with simpler goals. Therefore, the opportunities and the ways data science can be used for project outcomes are plenty. In the business industry, it may seem like if one have gained the competitive advantage, one succeeded. However, the reality is more complex than that. What we see as end results are achieved after rigorous efforts. And most of these efforts could have been years in the making; not to mention the cost that is incurred. In today's era, business success also depends on the efficiency and effectiveness of the invested hard work. Time and cost would mean nothing if a business is not making a significant difference in the industry or maintaining the competitive edge. It is a constant race, where you have to care about impact at the same time as profit. So, wouldn't businesses like to save that money and time; invest in more lucrative projects at more appropriate times? And where will that knowledge come from? This is where data science for project management comes in (Kaisler et all, 2013). it is not the predictor of the future. That remains as unknown as before but we can make smarter decisions using data science. We can determine certain patterns and avoid previous mistakes. It allows to not finish risk but reduce it. If more and more projects could be streamlined with smart insights from interpreting data, businesses can truly enhance their productivity and performance. Also, they can manage this within lesser time and cost; two commodities as important the business world as data itself (Moyle&Jorge, 2001). But data science is not just merely about the efficacy of projects.

In conclusion, we can say that project management and data science should be used in combination. Given our current business world environment and how both fields are growing steadily, this combination can be a powerful strategy for success. The success of a business relies on the success of varying projects. If the project managers are allowed a collaborative knowledge of data science, it can help businesses not only achieve competitive advantage but maintain for longer time periods. This is not only true for big companies and institutions but the small businesses as well. They are often more vulnerable to the risk of market and less equipped to deal with loss of money. We can truly change the dynamic with this powerful integration of skills.

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Reasons for Cost Overruns in the Construction of Highways in Croatia

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Abstract:

Due to the importance and impact of large infrastructure projects on the economy, the reasons for cost overruns, which are almost inevitable with such projects, are of great interest to researchers and practitioners. Flyvbjerg et al. (2002) indicate that 9 out of 10 projects have cost overruns, while Love et al. (2019) talk about 47% (i.e., ≈ 5 out of 10) of projects that deviate from the approved budget. In studies, the most common way of analyzing cost overruns and delays is based on listing the various factors that cause these problems, often supported by a ranking system. However, the fact that two almost contradictory approaches to explaining the reasons for cost overruns, evolutionist and psycho-strategic, have emerged in the scientific literature is a really confused. The paper examines the reasons for cost overruns based on the example of road infrastructure construction in the Republic of Croatia, based on specific documentation or records of the contractor's request for additional works. The goal is to determine the structure of the reasons, categorize them, and position it within the established theoretical explanations of the sources of cost overruns. The dominant reasons for cost overruns relate to the elimination of deficiencies in project documentation and modification of technical solutions due to unforeseen natural conditions. The importance of mature technical solutions is emphasized for making reliable assessments. The timely start of the development of projects is of crucial importance without on fact what kind of risks for cost overrun we gone face.

Keywords: *highways; cost overrun; cost estimation*

1. Summary

Practice has shown that cost overruns accompany many infrastructure projects (Flyvbjerg, et al., 2002; Flyvbjerg, et al., 2018; Cantarelli, et al., 2012; Odeck, 2014; Steininger, et al., 2021), and is present in all geographical areas. The financial, social and environmental performance of infrastructure investments is actually extremely weak (Ansar, et al., 2016), and 9 out of 10 (Flyvbjerg, et al., 2002), or 5 out of 10 projects (Love, et al., 2019) has cost overruns. Odeck (Odeck, 2014, p. 71) presented twenty-one studies for different countries of the world where a large range of average cost overruns is observed, from 4.5% to 86% of average cost overruns. The problem of cost estimation is of an economic nature, because incorrect cost estimation can lead decision makers to implement ineffective policies. In addition, cost overruns can cause legal problems (Lovrinčević & Vukomanović, 2022), public investigations (Odeck, 2014) and negative perception (Siemiatycki, 2009; Samset & Volden, 2016). Due to the frequency and negative impact on investment expectations, there is a great interest in understanding the reasons for overruns, whether they are public or private clients, contractors, planners, employees of public organizations, project managers and the like. In studies, the most common way of analyzing cost overruns and delays is based on listing the various factors that cause these problems, often supported by a ranking system (Adam, et al., 2017, p. 402). In the scientific literature, a dilemma is posed as to what is truly the source of the problem of cost overruns, and two approaches to understanding the reasons for cost overruns have been profiled (Love, 2011). Evolutionists approach is based on the sources of overruns associated exclusively with project features, i.e., changes in the scope of the project, the complexity of complex decisions, and the definition of the key points of the project, i.e., the moment in relation to which the assessment is made. In contrast, psycho-strategists attribute overruns to deception, planning fallacy and unjustifiable optimism in the setting of initial cost targets (Love, 2011). Flyvbjerg et al. (Flyvbjerg, et al., 2018) believe that the visible reasons for the overruns as well as the mitigation mechanisms are not unknown to planners, but they are neglected due to bias, overconfidence, planning errors and strategic misrepresentation. They believe that changes in scope are often misunderstood as the cause of cost overruns simply because they are more visible than the underlying causes. They are manifestations, and prejudice and underestimation are the root causes of cost overruns. In behavioral terms, the causal chain begins with human bias that leads to underestimation of scope during planning, which is the cause of unexplained changes in scope during delivery and cost overruns.

The article will investigate the reasons for the cost overruns of specific contracts for the construction of sections of the highway network in the Republic of Croatia and try to understand the real reasons for the overruns. The introduction is followed by a second paragraph in which the reasons for the overruns identified through the reviewed literature will be summarized. The third paragraph defines the problem and subject of the research, and the fourth defines the research methodology. The results of the research are presented in the fifth chapter, the limitations of the research in the sixth, and the conclusion in the seventh.

2. Review of the literature on the risks and reasons for cost overruns

Indeed, very often it is not easy to clarify the source of cost overruns, nor to clearly define what the consequence is and what the cause is. For example, for factors related to the categories Communication (Lack of communication between contractors and clients, inefficient communication) and Psychology (Optimism bias, deception) Adam et al. (Adam, et al., 2017, p. 402) research assigned low scores, i.e., less impact on cost overruns and delays. However, they emphasize that this does not necessarily undermine their importance in causing delays and cost escalations. They leave open the possibility that issues related to communication or psychology were the underlying causes behind factors such as improper coordination or poor cost estimation, both of which are categorized differently in the examined papers. In contrast, Durdyev (2020) does not even have these reasons in the explanation of the "Inaccurate cost estimation" category. Namely, Adam et al. (2017, p. 401) explaining that during the determinations the cause of delay and cost increases, it is not always possible to ascertain where the actual cause occurs in the chain of events that unfolded prior to the occurrence of the delay and cost increase. For example, it can be argued that solution manipulation is a subset of improper planning and that deception is an indicator of poor employment policies (2017, p. 401). When using the research results that categorize the reasons for cost overruns, it must be kept in mind that these are simplified models. Bhargava et al. (2010) proved that there is a simultaneous relationship between cost overruns and time delay, which makes understanding the reasons for overruns even more complex. Table 1.

shows the risks to the price and term of infrastructure facilities, and the reasons for cost overruns highlighted in the reviewed literature.

Table 1 .: An overview of some examples of reasons and risks of cost overruns

Source name	Reason for cost and time overruns, risks affecting price and term
EU framework (1998), *Understanding and Monitoring the Cost-Determining Factors of Infrastructure Projects A User's Guide,* p. 12.	unexpected ground conditions, design changes, poor project management, land acquisition costs, inflation/relative price changes, force majeure, shortage of material and plant, exchange rate, inappropriate contractors, funding problems
ECORYS Transport, (2005), *Ex Post evaluation of a sample of projects co-financed by the Cohesion Fund (1993-2002), Synthesis Report, Final Report*, Rotterdam: European Commission, DG Regional Policy, p.65.	poor project preparation, external factors, community involvement, lack of managerial capability
Vu, H.A., Wang, J.Q., Min, L.X., Mai, S.H. and Nguyen, H.P. (2016) , Research on Cost Overrun Risk of Construction Phase of Vietnam Highway International Contracting Project	infrastructure construction investment management system factor, survey and design scheme factor, capital and contract constraint factor, construction unit fiscal and management ability factor, land requisition factor, macro-economic environment change factor and supervising moral risk factor
Park, YI., Papadopoulou, T.C., (2012) Causes of cost overruns in transport infrastructure projects in Asia	contract awarded to lowest bidder, inadequate site investigations, unforeseen site conditions, inadequate pre-construction study, inaccurate estimates, inadequate duration of contract period, incompetent subcontractor, inappropriate procurement route/contract, poor site management by contractor,
Asiedu R.O., Adaku, E., (2019), Cost overruns of public sector construction projects: a developing country perspective	Poor contract planning and supervision, change orders, weak institutional and economic environment of projects, lack of effective coordination among contracting parties
Lee, Jin-Kyung (2008), Cost Overrun and Cause in Korean Social Overhead Capital Projects: Roads, Rails, Airports, and Ports	changes in the scope of the project, delays in construction, unreasonable estimations and adjustments of the project costs, no practical use of the earned value management system
Al Hazim et al. (2017):	terrain conditions, weather conditions, variation orders, availability of labor, mistakes in design, planned costs for project construction, market conditions (availability of resources), material price fluctuations, planned time for project construction, emergency works

Furthermore, Durdayev (2020) investigated the literature on cost overruns, i.e., the frequency of occurrence of a particular reason in published articles. The reasons shown with the number of occurrences are: Design problem and incomplete design (23), Inaccurate estimation (23), poor planning (20), weather (18), poor communication (17), stakeholders' skills, experience and competence (18), financial problems/poor financial management (17), price fluctuations (16), contract management issues (15), ground/soil conditions (14).

Adam et al. (2017), on the other hand, determined the connection of the dominance trend of the appearance of a particular reason for cost overruns (Project, Management, Organizational, Material, Communication, Psychological, Weather, Financial) with time periods (1985.-1990., 1991.-1996.-, 1997.-2002., 2003.-2008. and 2009.-2014.). He noted that in the time intervals he monitored, the studies recorded different dominances and rankings of individual reasons for overruns.

However, the fact that a particular reason was cited the most does not answer the question of why this is so. From the research presented, we cannot draw uniform conclusions because there is no uniformity in the arrangement and structure of the reasons either geographically or terminological. In explaining the occurrence of cost overruns, two strongholds developed, whose representatives fiercely confronted each other in published works (Love & Ahiaga-Dagbui, 2018; Flyvbjerg, et al., 2018). The differences in the explanations are essential. For the former, "Optimistic Bias" and "Strategic Misrepresentation" (lying) are the two main sources of misinformation (Flyvbjerg, 2007; Cantarelli, et al., 2012b; Flyvbjerg, et al., 2002). On the other hand, critics of the psych-strategic approach emphasize it is ignorance and disregard for complexities and nuances of the design and estimating process of transport infrastructure projects (Love & Ahiaga-Dagbui, 2018, p. 358).

Love and Dagbui (2018) agree that planned strategic misrepresentation, systematic distortion or misrepresentation of facts in the budget planning process in the public sector is a widespread practice. However, according to them, this cannot be an explanation for the underestimation of costs, such a claim is disinformation of a sensationalist nature that has found fertile ground due to the inability of the public sector to deal with the phenomena of underestimation of costs. They believe that such an explanation discourages the improvement or optimization of project practices, encourages overestimation and shows a lack of understanding of project development. They argue that cost estimates suffer from error, not bias, and no empirical evidence has been shown that optimistic bias, political-economic explanations, and strategic misrepresentation directly contribute to cost underestimation in transport infrastructure projects. Eliasson & Fosgerau (2013) come to the same conclusion and explain that it is possible that the forecasts are actually unbiased, but that the selection of the best projects, under the influence of the same forecast, leads to bias. All that is essential for the presence of bias in the assessment of project selection is that there is some kind of selection process in the procedure, whereby the selection is influenced by "noisy" prediction. Regardless of malign practices or unproven optimism, infrastructure projects are still subject to significant corrections, mostly resulting from design changes and errors (Love, 2011, p. 1198). In a way, this theory is supported by claims about the connection between project size and cost overruns (Adam, et al., 2017), because large infrastructure projects are complex and hide more unknowns. Using the example of Asia, Park and Papandopoulou (2012, p. 211) found that long projects are more susceptible to unforeseen events and changes in their original design due to technological progress, and high and unstable inflation in Asia, which has a greater impact on longer projects. A similar conclusion that the cost increase strongly depends on the length of the implementation phase and that larger projects have a higher percentage of cost increase is given by Flyvbjerg et al. (2003).

3. Problem and subject of research

The presented situation shows the non-uniformity of terms and explanations of the reasons for cost overruns, as well as the wide range in the amounts of cost overruns among studies on cost overruns for individual countries. Table 2. shows the frequency and size of the cost overrun determined by research conducted by a number of authors by individual countries and geographical areas (Cantarelli, et al., 2012b, p. 50). Cost overruns are shown for three categories of facilities, namely: roads, railways and fixed facilities, which includes viaducts, tunnels and bridges that appear on infrastructure facilities.

Table 2. : Comparative presentation frequency and magnitude of cost overruns found in literature

Source: Cantarelli, CC, Molin EJE, van Wee, B, Flayvbjerg, B, 2012, Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases, Transport Policy, 22, p. 50

Study	Geographical area	Frequency cost overrun (%)	Magnitude of cost overrun							
			Road		*Rail*		*Fixed Links*		*Other*	
			%	N						
Merewitz (1973)	US	79	26	49	4	7				
Morris (1990)	India				64	3				0
Pickrell (1990, 1992)[b]	US	88			1					
Auditor General (1994)[c]	Sweden		86	8	7					
Nijkamp, Ubbels (1999)	Netherlands, Finland	75							-20	
Bordat et al. (2004)	US	55	5	2668[d]						
Odeck (2004)	Norway	52	8	620						
Dantata et al. (2006)	US	81			0	6				
Ellis et al. (2007)	US		9	3130						
Lee (2008)[e]	South Korea	95	11	138	8	6				
Flyvbjerg et al. (2003a)	World	86	20	167	1	8	4	3		

a) In which: (%) the percentages cost overrun and N: the number of projects with cost overruns

b)Source: van Wee (2007)

c) Source: Odeck (2004)

d) Projects include: Road and bridge Construction and rehabilitation projects, maintenance projects, with road maintenance and resurfacing contract; Traffic and traffic maintenance contract

e) Source: Siemiatycki (2009)

From the presented research, it is concluded that there is a large range of determined overrun ranging from 20% to 164%. Although, according to the conclusion of the authors of the study, they differ in the use of cost prices (nominal or real prices), moment for the year of decision to build and actual cost, sample size and geographical areas, the difference is drastic. If this is compared with the results of the study at the world level, it is concluded that in addition to differences in cost overruns between countries, there is also an important difference from the average cost overruns at the world level. Flyvbjerg et al. pointed out the differences in the average increase in costs by individual types of transport projects and geographical areas as far back as 2002. (Flyvbjerg, et al., 2002). Table 3. shows the results of studies of 258 projects distributed according to three geographical areas: Europe, North America and other geographical areas.

Table 3. : Data on cost overruns by geographic area and project type

Source: Bent Flyvbjerg, Mette Skamris Holm, and Søren Buhl, "Underestimating Costs in Public Works Projects: Error or Lie?" Journal of the American Planning Association, vol. 68, no. 3, summer 2002

Type of projects	Europe			North America			Other geographical areas		
	Number of projects (N)	Average cost escalation (%)	Standard deviation	Number of projects (N)	Average cost escalation (%)	Standard deviation	Number of projects (N)	Average cost escalation (%)	Standard deviation
Rail	23	34,2	25,1	19	40,8	36,8	16	64,6	49,5
Fixed Links	15	43,4	52,0	18	25,7	70,5	0	-	-
Road	143	22,4	24,9	24	8,4	49,4	0	-	-
Total	181	25,7	28,7	61	23,6	54,2	16	64,6	49,5

From the data presented, it is evident, for example, that the average increase in costs for Europe in the group of objects "Roads" is 22.4%, which is significantly higher than 8.4% for the same group of objects in North America. At the same time, in the same geographical area, it is lower than the average cost overrun for the second group of "Rail" facilities. A very significant difference was observed in the group "Other geographical areas" (ten developing countries and Japan), namely 64%.

Asian International Infrastructure Transport Projects also face a lot of pressure regarding the basic cost difference due to their chaotic market structure (Al-Hazim, et al., 2017). About 76% of projects spend more than estimated, while 24% underestimate costs. The difference between the actual price and the estimated price of construction projects is on average about 15% (Al-Hazim, et al., 2017). In Korea, in the case of roads, 95% of projects have a maximum cost overrun of 50%; while 100% of railway projects have a maximum cost overrun of 50%. In Korean mega capital projects of traffic construction projects, the probability of cost overruns from 95% to 100% is over 50%. (Lee, 2008). Data on the distribution of cost overruns is presented in Table 4. (Cantarelli, et al., 2012b).

Table 4.: Average cost of escalation in 258 transport infrastructure projects

Source: Bent Flyvbjerg, (2007) "Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure," *Transportation Planning and Technology*, vol. 30, no. 1, February 2007

Type of project	Number of projects (N)	Average cost escalation (%)	Standard deviation	Quartiles (25/50/75 %)
Rail	58	44.7	38.4	24/43/60
Bridges and tunnels	33	33.8	62.4	-1/22/35
Roads	167	20.4	29.9	5/15/32
All projects	258	27.6	38.7	5/20/35

The presented data point to different structuring of cost overruns of individual groups of projects. Means and standard deviations are significantly different for different types of projects. Road projects have the smallest average overrun and the smallest standard deviation, and fixed links have a higher standard deviation than railways even though they have a smaller average overrun.

It can be concluded that research that will monitor cost overruns according to the types of projects in a specific geographic area can significantly contribute to understanding the issue of cost overruns. Love et al. (2019) state: "An issue that has hindered progress being made to address this problem has been the availability of empirical data that reflects the changing nature of cost estimates and their divergence from project's final account."

This research provides just that. Based on empirical data on the reasons for overruns collected at the source from strict project documentation, and not on the retrospective views of construction participants, we want to present knowledge about the specific project.

4. Research methodology

After achieved its independence, the Republic of Croatia carried out intensive construction of the road network, since over 1000 km of highways were built in the post-transition period, or five times more than in the entire previous period of existence, which represents an opportunity to research the reasons of the cost overruns. We aim to objectively determine the reasons for the deviation of the actual from the contracted costs of road infrastructure projects in the Republic of Croatia in order to provide explanations of the phenomenon. The research refers to the period after contracting, which is the result of an international public tender. The contract price represents a kind of assessment for which the selected bidder believes that they can successfully implement the contract with a satisfactory profit. By signing the contract, it becomes the reference amount for both parties, according to which resources, income and expenses will be planned. We analyze the reasons that caused the overrun of the contracted costs, which are read through requests for additional works, which were not agreed between the contracting parties. As a criterion of good practice, the principle of data availability is used for sampling (Flyvbjerg, et al., 2002; Flyvbjerg, et al., 2018), on the basis of which 8 contracts were analyzed and a sample of 562 requests from contractors for reimbursement of additional costs were formed. In the subject research, there is no finite number of units in the population. The random selection of the data ensured that the sample was representative (at least in an average sense) of any characteristic that might bias the sample and distort the features. A representative sample means that each characteristic (and combination of characteristics) occurs the same percentage of the time in the sample as in the population, and the selection of the sample is not the result of any bias. By not sampling on the basis of any measurable characteristic, the random sample is statistically free of bias and therefore representative. It represents the best information we have about an unknown parameter, or population. The sample statistic is represented by the number of occurrences of a particular reason for exceeding (population parameter), i.e., its financial significance. There is a natural correspondence between the statistic (the sample) and the parameter (the population) and it is conditioned by the quality of the sample. Following this principle, the investigation of the reasons for cost overruns was started on the basis of documentation from specific projects, i.e., records of the contractor's requests for additional works, which resulted in a change in costs. Recorded approved requests, consents and contracts for additional works with the ability to influence the costs of the population of road projects are separated from the documentation. The sample statistics of the categorical nominal variable "risk type" are represented by the frequency of occurrence. On the other hand, the sample statistics of the discrete random variable of the financial value of a particular category is represented by the frequency of the financial share. Descriptive statistics were chosen for the research as a necessity, given that due to the large number of risk categories in relation to the size of the samples, it was not possible to perform statistical testing. In order to reduce the number of variables, and in accordance with the needs of statistical research, the sample was categorized and the research variables became risk groups. To prove the hypothesis, data that were risks in the project preparation phase are used, but the consequences of these risks are recorded as additional costs of the activities actually performed. The procedure includes defining a statistical data set, i.e., recording and categorizing risks, recording the number of occurrences of a particular risk category in the data set, and recording the financial value of a particular risk category. Based on the collected data, the statistical characteristics of the sample will be determined, namely the frequency and relative frequency of each category, that is, the ratio of frequency to the total amount of data in terms of the number of occurrences and financial frequency. The collected 562 requests have a financial value of HRK 1.4 billion, and were categorized by grouping risks into categories formed for this purpose. Considering the influence of the specificity of the geographical area on cost overruns, the categories established by Burcar Dunović, Radujković and Vukomanović (2013) will be used as the basis for risk analysis. The authors used the Risk Breakdown Structure (RBS) or the developed risk structure by applying the hierarchical approach of the developed work structure (WBS – Work Breakdown Structure) to risks.

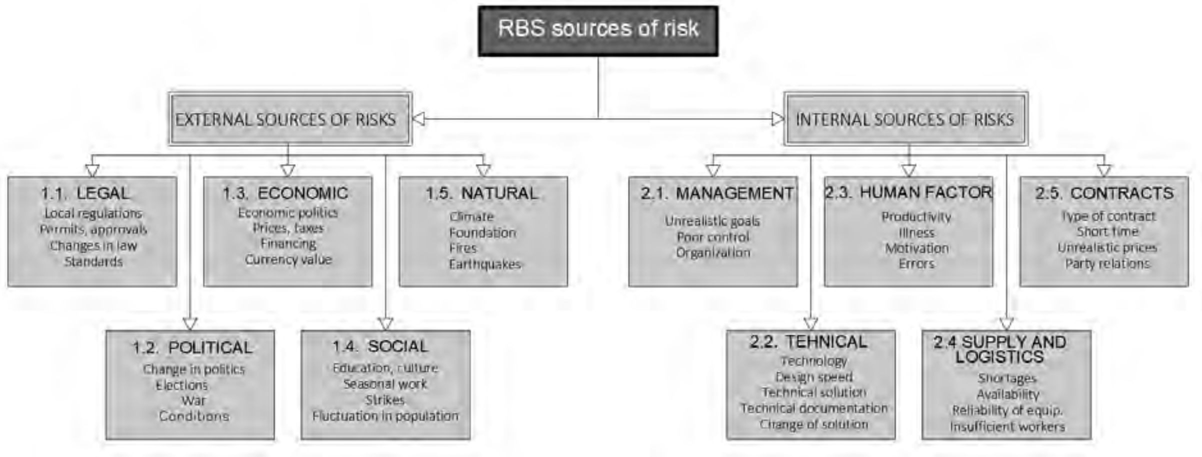

Chart 1: Structure of risk sources for the risk register of construction projects

Source: Burcar Dunović, I., Radujković M., Vukomanović M., Razvoj i implementacija registra rizika kod građevinskih projekata, GRAĐEVINAR 65 (2013, p.25).

Chart 1 shows the developed risk structure applied to the risk register of construction projects in the Republic of Croatia. By structuring problems in risk management to the level necessary for understanding risk exposure for the purposes of effective management, the authors presented RBS applied to the risk register of construction projects in the Republic of Croatia. The statistical processing and formation of the database was based on the identification of reasons for price increases (risks) and classification by type of risk, and financial amounts according to consents as a preparation for data analysis and interpretation.

The goal of the statistical analysis is to determine the representation of a certain category or risk in the observed sample, and its financial share. The variable, which we will mark with X (RISK), has 10 categories (k = 10). Table 5 shows the risk categories formed for the purposes of this research taken from Burcar Dunović et al. (2013).

Table 5. : Categories of the variable "Risk" (Burcar Dunović, et al., 2013)

VARIABLE "RISK"	
	CATEGORIES
	LEGAL SOURCES OF RISKS
	POLITICAL SOURCES OF RISK
	ECONOMIC SOURCES OF RISK
	SOCIAL SOURCES OF RISK
	NATURAL SOURCES OF RISK
	MANAGEMENT
	TECHNICAL SOURCE OF RISK
	HUMAN FACTOR
	SUPPLY AND LOGISTICS
	CONTRACTUAL

The distribution of observed cost values will be monitored for categories x1,..., x10 of X (n=10). Frequency is the number of occurrences of an individual xi in the sequence x1,...,x10, and the relative frequency of xi is the number of measured values of the variable belonging to the category xi divided by the total number of measured values for the examined variable, i = 1,...,10. The frequency of a particular category depends on the number of measurements performed, i.e. the size of the sample. If n is the sample size, i.e. the number of all measured values of the examined variable, we calculate the relative frequency of category xi as

$$f = f_i / n \qquad (1)$$

Relative frequencies are expressed for the purpose of comparing and interpreting research results as a measure that provides information about the proportion of a category in a sample of known size and will be presented as a percentage. Frequencies and relative frequencies of individual categories will be presented tabular and graphically using pie charts.

5. Research results

The results of the research are graphs and tables of frequency distribution, and the ranking of individual risks in the researched projects is achieved through statistical analysis. For this purpose, frequencies and relative frequencies of occurrence will be tabulated and graphically presented.

Table 6 shows the structure of risks that became requests from the contractor to the client according to the number of occurrences, from which we can see that out of 562 requests, the most related to risks from the technical source of risk group.

Table 6.: Impact of risk on the price according to the number of requests from the contractor to the client

NUMBER OF REQUESTS ACCORDING TO RISK SOURCES											
CONTRACT	TOTAL NUMBER OF REQUESTS	LEGAL SOURCES OF RISKS	POLITICAL SOURCES OF RIS	ECONOMIC SOURCES OF RISK	ECONOMIC SOURCES OF RISK	NATURAL SOURCES OF RISK	MANAGEMENT	TECHNICALI	HUMAN FACTOR	SUPPLY AND LOGISTICS	CONTRACTUAL
Dugopolje Šestanovac	196	4	0	0	0	74	20	88	0	0	10
Čvor Ploče-Granica BiH	46	0	0	0	0	4	8	32	0	0	2
Čvor Ploče-Ploče 1	88	0	0	0	0	23	16	43	0	0	6
Velika Gorica -Lekenik	26	0	0	0	0	5	0	19	0	0	2
Cesta Meterize	23	0	0	0	0	0	0	23	0	0	0
Tunel Sv. Ilija	40	0	0	0	0	16	1	21	0	0	2
Šestanovac Ravča	112	0	0	0	0	43	2	59	0	0	8
Zlatar Bistrica- Antunovac	31	0	0	0	0	4	0	27	0	0	0
SUM:	562	4	0	0	0	169	47	312	0	0	30
SHARE OF THE NUMBER OF REQUESTS:	100,00%	0,71%	0,00%	0,00%	0,00%	30,07%	8,36%	55,52%	0,00%	0,00%	5,34%

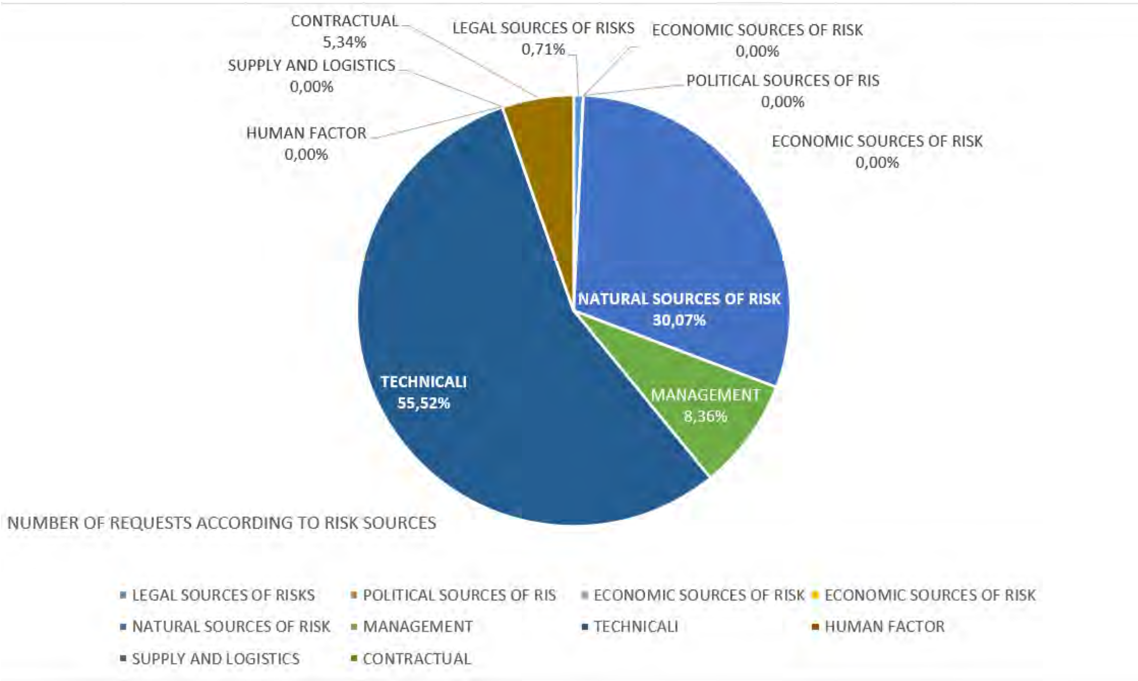

Chart 2: Share of individual risk groups in the total number of requests

Chart 2 shows the share of individual risk groups that became the contractor's requirements towards the client in the total number of requirements. The dominance of technical sources of risk is visible, because by the number of requests, more than half have their source in low-quality designs. We can observe the same risks through the financial impact.

Table 7, according to the financial impact, shows the structure of the risks that became the contractor's requirements towards the client.

Table 7.: Impact of risk on price according to financial value

	FINANCIAL VALUE OF THE CONTRACTOR'S CLAIMS BY SOURCE OF RISK										
CONTRACT	TOTAL NUMBER OF REQUESTS	LEGAL SOURCES OF RISKS	POLITICAL SOURCES OF RISKS	ECONOMIC SOURCES OF RISK	ECONOMIC SOURCES OF RISK	NATURAL SOURCES OF RISK	MANAGEMENT	TECHNICAL	HUMAN FACTOR	SUPPLY AND LOGISTICS	CONTRACTUAL
Dugopolje Šestanovac	557.176.994,63 kn	0	0	0	0	114.334.236,65 kn	1.991.603,92 kn	415.883.322,90 kn	0	0	24.967.831,16
Čvor Ploče-Granica BIH	1.859.176,55 kn	0	0	0	0	153.750,75 kn	555.250,51 kn	1.014.514,71 kn	0	0	135.660,58
Čvor Ploče-Ploče 1	250.394.224,18 kn	0	0	0	0	18.994.219,30 kn	20.021.623,66 kn	161.484.480,11 kn	0	0	49.893.901,11
Velika Gorica -Lekenik	15.843.005,31 kn	0	0	0	0	647.991,76 kn	0	10.381.104,92 kn	0	0	4.813.908,63
Cesta Meterize	1.269.529,92 kn	0	0	0	0	0	0	1.269.529,92 kn	0	0	0,00
Tunel Sv. Ilija	112.977.916,31 kn	0	0	0	0	11.295.633,79 kn	62.880,51 kn	94.210.714,86 kn	0	0	7.408.687,15
Šestanovac Ravča	453.114.308,35 kn	0	0	0	0	75.611.985,44 kn	7.187.526,93 kn	342.626.709,04 kn	0	0	27.688.086,94
Zlatar Bistrica- Antunovac	1.961.095,01 kn	0	0	0	0	336.594,98 kn	0	1.624.500,03 kn	0	0	0,00
SUM:	1.394.596.250,26 kn	0,00 kn	0,00 kn	0,00 kn	0,00 kn	221.374.412,67 kn	29.818.885,53 kn	1.028.494.876,49 kn	0,00 kn	0,00 kn	114.908.075,57
SHARE OF THE FINANCIAL VALUE:	100,00%	0,00%	0,00%	0,00%	0,00%	15,87%	2,14%	73,75%	0,00%	0,00%	0,08

The total financial impact of the risk is HRK 1,394,596,250.26, and the greatest financial impact was caused by risks related to the technical source of risk, amounting to HRK 1,028,494,876.49.

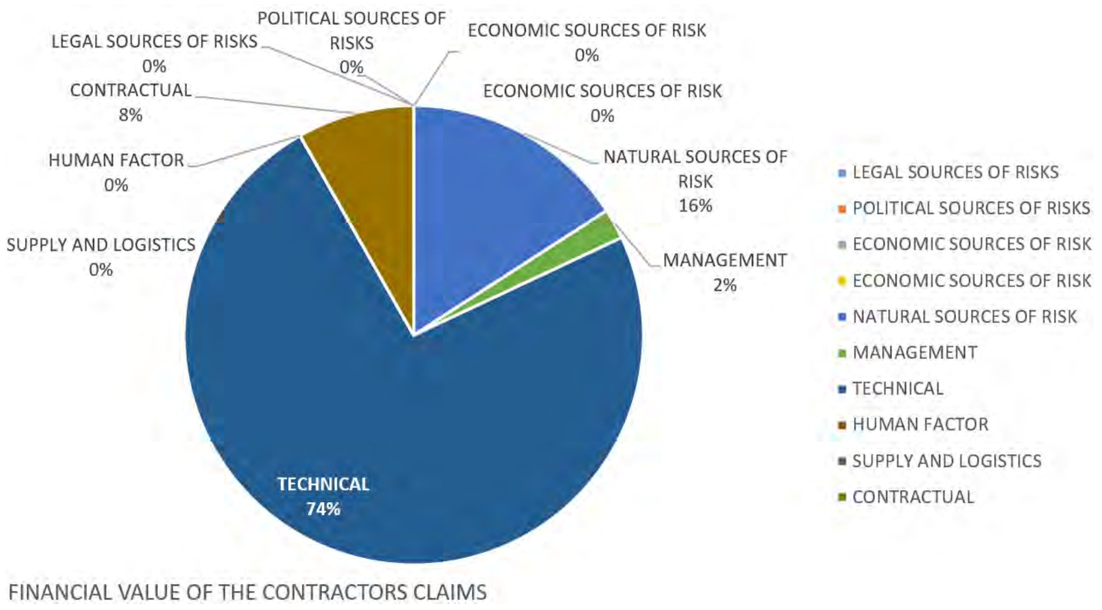

Chart 3: Share of individual risk groups by financial value

Chart 3 shows the financial share of individual risk groups in the total financial amount. The dominance of the influence of the contractor's requirements, represented by risks from the technical risk source group, is visible. The relative frequency of influence of the displayed sources increased financially in relation to the number of appearances. In terms of the number of requests and the financial share, the risks associated with technology, design speed, technical solution, technical documentation and change of solution dominate, followed by risks from the unpredictability of natural conditions encountered during implementation.

6. Research limitations

Although it is a significant sample, the limitation of the research is the fact that, in accordance with world experience, it was difficult to obtain data, and the data is limited only to a part of the projects realized at that time. Even in the best of circumstances, it is difficult to find valid and reliable data on the performance of infrastructure investments (Flyvbjerg, et al., 2002; Ansar, et al., 2016). The method of selecting the sample makes it representative, but we must be aware that it is not about the absolute representativeness of the population, because availability does not necessarily mean representativeness. In particular, the results do not guarantee representativeness in terms of the frequency of a particular overrun reason in the total population of overrun reasons, but they indicate the nature of the cause. In addition, it is evident that different quality of explanations is required, and there is probably a certain level of subjectivity when categorizing reasons. Namely, it is very likely that someone else would classify some of the analyzed reasons into a different category. For example, one of the analyzed requests approving a change in the project solution, which replaced the contracted viaduct with an embankment secured by a retaining wall, is categorized as a change in the technical solution. However, it could also be classified in the category of contractual risks because it is a consequence of the opportunities provided by the contract in terms of savings. The question arises whether the reason for the overrun is the fact that the designer, due to objective or subjective reasons, did not see that the solution with the wall is more favorable than the solution with the viaduct, so it is a technical reason for the overrun. Or maybe the solution with a viaduct is more favorable and logical than expected and is the correct technical solution, but for some particular reasons it is cheaper for the specific contractor to build an embankment and a wall, so the reason for the overrun is contractual. However, the impartiality and quality of the sample gives us the basis to believe that the obtained data represent quality information about the nature of the sample and that individual reasons that intersect do not affect the information about the nature of the population from which the sample was taken. Finally, we must be aware that the projects were investigated after the signing of the contract, which probably did not record the potential risks that occur in the earlier stages of the contract, which in a certain sense is also a limitation of the research. This is reflected in the fact that certain risk categories were not identified by research. It is very likely that research in the earlier development phase of the projects would have indicated other reasons for the overrun, which were eliminated as the project developed.

7. Conclusion

The aim of the research was to provide an explanation of cost overruns based on concrete data and to contribute to their understanding. Descriptive statistics proved to be appropriate for the investigated problem, and the risks affecting the deviation of the actual compared to the estimated costs of road infrastructure projects in the Republic of Croatia were recognized. Burcar Dunović et al. (2013, p. 26)conclude: "The creation of a database of good and bad implementations inevitably promotes development in terms of improving construction project management practices." Combined with the proposed risk register system model (Burcar Dunović, et al., 2013) the results research can provide significant information about future projects.

It turned out that the dominant reasons for overruns are of a technical nature, whether additional costs are aimed at eliminating deficiencies in technical documentation, or whether technical modifications are required due to unforeseen natural conditions. The recorded reasons for the cost overruns point to the importance of mature technical solutions for making reliable estimates. This conclusion is in contrast to the frequent occurrence in practice when, due to various pressures, assessments are made before the technical solutions have been well developed. Therefore, it is necessary to insist on the timely start of the development of technical solutions so that they can achieve satisfactory quality.

The presented research results can be used to get a picture of the reasons for exceeding the population of road projects in the Republic of Croatia, but not for the exact explanation of the reasons for the exceeding. The recorded reasons are predominantly of a technical nature, and then also due to the changed natural conditions that were established during the implementation. The complexity of large projects should not be dismissed as one of the origins of cost overruns. The research showed that the dominance of technical reasons indicates that it is not possible to include the specifics of large projects in a repeatable matrix, given that every new project hides surprises that cannot be seen in the design and planning phase due to various reasons.

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The Role of Agility and Sustainability in Digital Transformation

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Abstract:

The paper presents the results of research on the possibility of integrating the concept of sustainable development with agile project management. An agile approach helps organizations implement their initiatives more efficiently and is a driver of digital transformation, which in turn helps improve performance. Integrating with the concept of sustainability and taking advantage of digital transformation results in a faster response to technological challenges in environmental protection and enables a more appropriate response to community needs, which contributes to global business development in a sustainable manner. According to the research results, stakeholder participation and interest of stakeholders are the most significant sustainability principles in all project management phases. Related to this, it can be concluded that stakeholders need to be involved in the process of digital transformation from the beginning, and moreover, that the lack of communication and participation of stakeholders can be seen as one of the causes of the failure of digital transformation projects.

Keywords: *agility; sustainability; project management; digital transformation*

1. Introduction

One of the most intensive changes that organizations struggle with today is related to digital transformation in business. Today, management is increasingly noticing that investing in digital transformation and accepting agile and digital processes is the basis for the survival and development of organizations in the future. It becomes significant to take on the advantages that this transformation brings to the business system. In the new digital environment, better decisions can be made using high-quality information. By using new technologies, it is possible to establish close relationships with clients and quickly react to new requirements, as well as to increase process efficiency through automation, and many other advantages. Moreover, organizations are trying to establish a balance between their profit goals and goals related to contributing to the well-being of society and protecting the environment. In an attempt to establish a balance, organizations are increasingly interested in the possibility of integrating the concept of sustainable development into business system. This concept is comprehensive because its dimensions: social, ecological, and economic, include all areas crucial for establishing balance.

In order to integrate the concept of sustainable development into the business system and all management levels, from strategic to operational, it is necessary to integrate the concept of sustainable development with other management concepts. One of those concepts is project management, since projects are implemented with the aim to achieve strategic goals. In this way, the strategy of sustainable development and sustainable business of the organization is implemented through sustainable project management. In order to adequately implement this management concept, one of the important decisions concerns the selection of an approach for managing projects in a sustainable manner. Toljaga-Nikolić et al. (2020) conclude that by using an adequate project management approach, organizations provide a strong foundation for introducing sustainability and obtaining better results. In circumstances when the environment imposes numerous changes during the project life cycle, organizations often apply agile methodologies in practice. In this way, they are the initiators of digital transformation, they contribute to a faster response to the requests of interested parties as well as to the protection of the environment through the application of modern digital technologies. According to Reis et al. (2018), organizations should adapt their strategies, activities, and processes for doing business in a new digital environment. As part of the conducted research, the possibilities of integrating the concept of sustainable development and agile project management were analyzed, emphasizing the particular importance of the sustainability principles in this process (Toljaga-Nikolić, 2022).

2. Sustainable development and sustainable project management

At the end of the 20th century, the concept of sustainable development became one of the most important thoughts in society and the business world. This was the result of increasingly serious consequences of decades of human development, which caused excessive consumption of raw materials and resources. At the same time there was no uniform well-being of society on a global level, and it became clear that the future of the new generations is uncertain. Individuals and institutions have begun to deal with the issue of sustainable development, considering that the coming generations should be given at least equal, if not greater, opportunities to develop the world in which they will live. With the aim to lay the foundations of an initiative that soon became imperative in the world, the World Commission on Environment and Development prepared a report in 1987 called „Our Common Future“. In the Report a sustainable development is defined as „Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs“ (WCED, 1987). Related to this, the three dimensions that sustainability includes were in the foreground, namely the social, ecological and economic dimension, since without simultaneous contribution to progress and development in all three fields, one cannot talk about sustainable development.

According to Daneshpur (2015), one of the most significant challenges today, both for organizations and societies, is sustainability, which can be seen as a key factor in project success. Moreover, managing projects in a sustainable manner is an important skill that needs to be developed, while in project-oriented organizations it is considered necessary to strengthen awareness of the issue of sustainability (Daneshpur, 2015). A project represents a mechanism for the implementation of the organization's strategy, therefore, introducing the concept of sustainable development at the project management level is critical for successful strategy implementation (Aarseth et al., 2017; Gareis et al., 2009). Linking the concepts of sustainable development and project management is a subject of great interest in science and practice (Sabini et al., 2019; Schoper et al., 2015). Magano et al. (2021) conclude that projects are viewed as an instrument for the sustainable development of organizations and society.

A project as a temporary endeavor undertaken to implement a certain strategy is characterized by time and resource limitations, changes, risk, and uncertainty. Existing approaches and methodologies for project management look at the project from the perspective of time, money, and quality, often not considering what happens to the project result project after the last phase of project management is completed and the result is delivered to the client. The focus is, first of all, on the delivery of results within the planned period, within the agreed budget and with quality. However, the results of the project may have an impact on the social community and the environment even after all phases of project management have been completed. For this reason, sustainable project management is of great importance in order to see the comprehensive impacts and effects.

In achieving a competitive advantage for an organization, the integration of sustainable development concepts into project management approaches and methodologies should be of great support. Stakeholders react very positively to a situation when an organization transparently expresses its intention to care for the well-being of the community and the environment (Chofreh et al., 2019). However, Banihashemi et al. (2017) state that, although a large number of organizations take sustainability into account in business, a large number of them still manage projects by applying inappropriate project management approaches and methodologies and achieving failure. Therefore, it becomes questionable whether certain approaches and methodologies for project management are open and ready to enable the integration of the concept of sustainability in a way that makes it applicable and useful. Agile methodologies were developed to overcome the limitations of traditional management and are characterized by flexibility and openness to change. The agile methodologies support is especially important when integrating sustainability into project management because of the existing and increasing level of complexity, uncertainty, and changes (Obradović, Todorović & Bushuyev, 2018; Fernandez & Fernandez, 2016).

Among the first authors who integrated the principles of sustainable development into project life cycle management in the manufacturing industry were Labuschagne and Brent (2006). The authors stated that by considering sustainability as a long-term-oriented and future-oriented concept, it is necessary to consider not only the complete project life cycle but also the project result and its subsequent impact. Their conclusion is also relied upon by Silvius et al. (2012), who point out that the integration of the sustainability concept into project management significantly expands the boundaries of the project management system, which is a holistic view important for understanding the concept of sustainable project management. For the purpose of the research in the field of sustainable project management, a part of which was used in the writing of this paper, the classification of sustainability principles presented in their work by Goedknegt and Silvius (2012) was applied. This classification was chosen as the most comprehensive and refers to the following nine principles of sustainability: Value and ethics; Holistic approach; Long-term orientation; Large volume; Risk reduction; Stakeholder participation; Responsibility; Transparency; and Interest of stakeholders. The research examined the possibility of integrating sustainability principles into different project management approaches and methodologies, and agile project management was also included in the research.

For the purposes of the research, the following four phases of project management were identified as significant for sustainable project management: programming; planning; execution and monitoring and closing and evaluation (Toljaga-Nikolić, 2022). The activities of the programming phase are particularly important in sustainable project management because this is where the long-term impacts of project results are analyzed, long-term priorities are determined, available resources from renewable sources are found, and long-term cooperation with stakeholders is established. It is necessary to program the project goals so that they are aligned with the strategic goals; provide a framework for project scope; and define and agree on the expected results of the project and their impact on the social, ecological, and economic dimensions of sustainability. All of the above should be accepted by the project stakeholders. The programming phase provides the framework for the next planning phase, in which concrete and feasible project plans are defined. These plans are approved after finalization, and it is important that they can be changed later if necessary during the execution of the project, which contributes to the flexibility of sustainable project management. In the execution and monitoring phases, project plans are implemented, project performance is determined, and performance reports are created, which are continuously reported to stakeholders. If necessary, changes are implemented and project plans are adjusted so that the result of the project that is finally delivered to the client is accepted and approved, which is also a measure of the project's success. The closing and evaluation phase includes the administrative closing of the project based on the final approval of the project owner and acceptance of the results by the client. It also includes archiving of lessons learned and evaluation, in order to examine and assess the impact of the project results on the dimensions of sustainability. Future impacts are also assessed because the result of the project can have a long-term effect on the social and environmental dimensions.

3. Agile approach and sustainable development

The traditional approach to project management has shown its limitations in practice, because it was not always possible to identify all future impacts, precisely define the client's requirements, or sequentially implement all phases without changes. Practice has shown a demand for the development of new approaches for project management that will correspond to new circumstances and different characteristics of projects, so agile project management was developed. A group of authors published the Agile Software Development Manifesto and, through four basic values, provided the basis for the development of agile methodologies for project management, which today has gone beyond the scope of exclusively software development management. The values of agile management presented by the authors of the Manifesto and on which the approach is based are the following (Agilemanifesto, 2001):

- Individuals and interactions over processes and tools;
- Working software over comprehensive documentation;
- Customer collaboration over contract negotiation; and.
- Responding to change over following a plan

By analyzing the first value „Individuals and interactions over processes and tools" in the context of sustainability, the focus is placed on individuals in the organization, their communication and cooperation, which favors the social dimension of sustainability, where the well-being of every employee is taken into account. The result of the project should be benefits for stakeholders, which will be applicable and functional, which is in line with the value „Working software over comprehensive documentation", because benefit is put in the foreground. The sustainability concept strives to establish and foster partnership cooperation with stakeholders rather than being negotiating parties, which also supports the stated value „Customer collaboration over contract negotiation" and contributes to the fact that the concept of agility has the potential to integrate with the concept of sustainability since the given values are aligned with sustainability considerations. The fourth stated value „Responding to change over following a plan" is also aligned with the necessary flexibility when it comes to sustainable business, since due to a greater number of integrated dimensions of sustainability, a long-term orientation that replaces the short-term and a greater number of stakeholders in the project, one can also expect a greater number of necessary changes during the project phases.

The relationship between agile project management and the social dimensions of sustainability was analyzed by Albarosa and Valenzuela Musura (2016). The research results emphasized that the application of agile project management affected the social dynamics of the organization in several ways. The impacts were directly related to the individual's health and capacity to exert influence, develop new competencies, and understand purpose and meaning. The application of agile project management had a positive effect on all four factors mentioned. For agile teams, it is stated that it is necessary to function in a sustainable manner in order to avoid working in stressful conditions, fatigue or illness, loss of motivation and commitment to the team (Measey, 2015). The authors conclude that agile project management influences individual motivation, which is observed to be high in this environment (McHugh et al., 2011), as well as personal empowerment (Tessem, 2014), on the basis of which it is concluded that there is a space for the integration of agile project management and sustainability dimensions. Additional adaptability is supported by the fact that the methodology provides a framework that helps the organization adapt the methodology to each project and organizational environment (Agilemanifesto, 2001), which provides a good basis for integration with other concepts, such as sustainability. It is considered that this methodology is essentially hybrid, as it consists of components such as: Scrum, Crystal Clear, Extreme Programming, Dynamic Systems Development Method (DSDM), Feature Driven Development and others, and this further emphasizes its openness to combine with other methodologies in practice. In addition, the eighth principle (of a total of 12) in the Agile Software Development Manifesto is about sustainability and emphasizes that agile processes promote sustainable development. As Obradović et al. (2021) conclude, project management in a digital environment contributes to more effective and efficient project management as it requires a lot of flexibility in planning, communication with an extended list of stakeholders due to the long-term impact of project results, and the application of new technologies and digital tools.

4. Research methodology, results and discussion

Research in the field of sustainable project management was conducted in May 2021. The online questionnaire was sent to project managers and other professionals in the project management field with a lot of experience in managing projects in different industries in Serbia and other countries. These contacts were provided from the authors' professional, academic, and business contact lists. For research purposes, a questionnaire was created based on a review of the existing literature in the field. One part of the questionnaire included questions that examined the extent to which existing project management approaches support the integration of sustainability into project management, which aims to develop sustainable project management. Before sending the questionnaire to the respondents, it was tested in order to confirm the validity and reliability of the questions. Preliminary testing of the questionnaire was carried out by four project managers with many years of experience. After a detailed analysis of their answers and recommendations, the final structure of the questions in the questionnaire was defined.

The questionnaire was sent to 352 contacts, and the total number of complete and valid responses was 207, which provided a response rate of 58.8%. Figures 1-4 show the demographic characteristics of the respondents. For statistical data processing, the IBM SPSS software package was used. Out of 207 respondents, there were 60% of male respondents and 40% of female respondents (Figure 1). Related to the sector in which projects were implemented, the private sector was represented by 53%, 40% of projects were implemented in the public sector, and the civil sector was represented by 7% (Figure 2)

Figure 1. Gender of the respondents

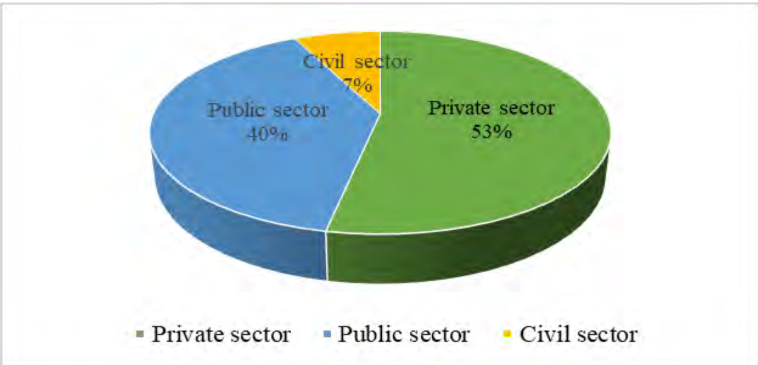

Figure 2. Ownership of the organization in which the project was implemented

Related to the industry in which the projects were implemented, the largest number was in the IT industry (38 in total), followed by education (24 in total), which are industries where digital transformation is very important. In order to examine the professional experience of the respondents, a question was related to the number of projects they had previously participated in and what position they held in the observed project. Their responses indicated a good sample in terms of expertise and experience. Namely, 66% of the respondents participated in more than 10 projects, and even 71% of the respondents held the position of project manager on the project that was the subject of the questionnaire (Figures 3-4).

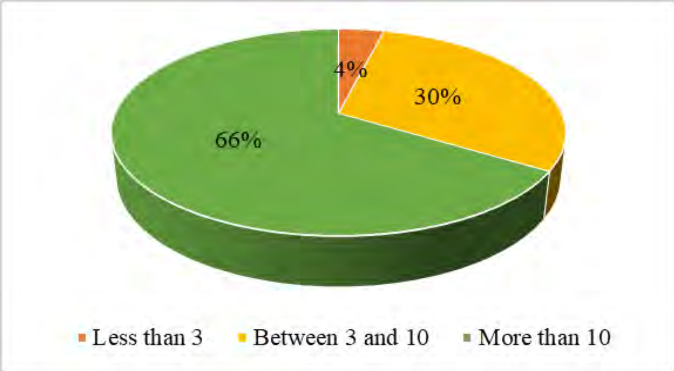

Figure 3. Professional experience of the respondents

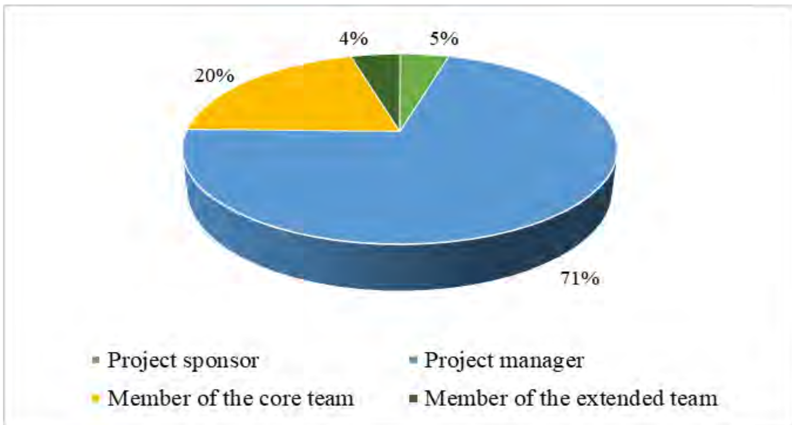

Figure 4. Project role of the respondents

With the aim of examining the readiness of agile project management to support the integration of sustainability principles through the project management phases, in Table 1 are presented the percentages of sustainability principles' participation in the project management phases.

Table 1. Percentages of sustainability principles' participation in the project management phases using agile management

	Value and ethics	Holistic approach	Long-term orientation	Large volume	Risk reduction	Stakeholder participation	Responsibility	Transparency	Interest of stakeholders	Value and ethics	Holistic approach	Long-term orientation	Large volume	Risk reduction
Programming	23.1	23.1	34.6	30.8	26.9	46.2	46.2	50	50	23.1	23.1	34.6	30.8	26.9
Planning	53.8	53.8	69.2	80.8	61.5	80.8	46.2	57.7	61.5	53.8	53.8	69.2	80.8	61.5
Execution and monitoring	53.8	38.5	34.6	26.9	57.7	61.5	34.6	53.8	57.7	53.8	38.5	34.6	26.9	57.7
Closing and evaluation	38.5	15.4	23.1	23.1	34.6	46.2	23.1	46.2	50	38.5	15.4	23.1	23.1	34.6

It can be concluded that the principles of transparency and interests of stakeholders were integrated to a greater extent in projects that were managed agilely in the phase of programming (with 50%). High percentages of integration of all sustainability principles are observed in the phases of planning, and execution and monitoring, which can be explained by the fact that project managers are still mostly focused on the activities of these two phases. It is important to emphasize here that the issue of sustainability in project management should be addressed from the very beginning, so that the management practice incorporates as early as possible all dimensions of sustainability important for the project. When it comes to the closing and evaluation phase, there is significantly less integration of sustainability principles in this phase, with the exception of the principle of interest of stakeholders, which also has the highest percentage integration in this phase of project management.

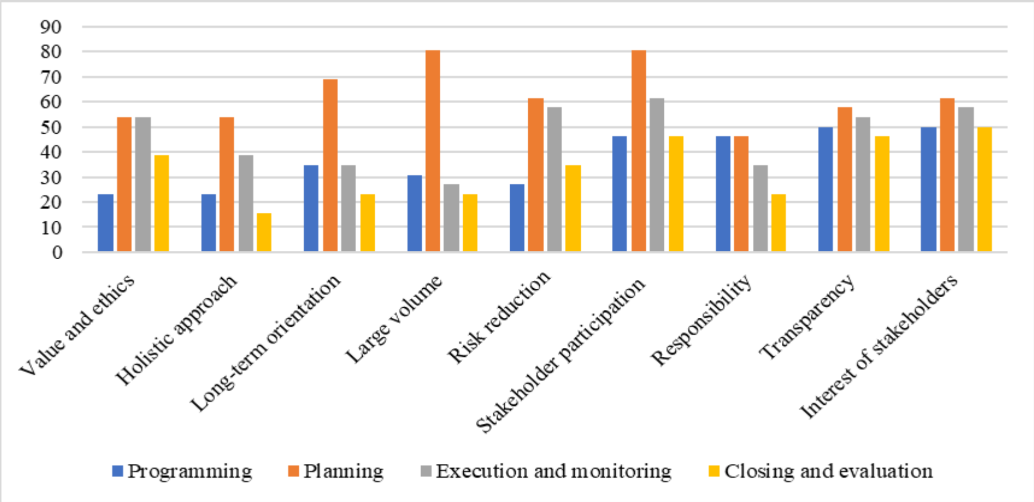

Figure 5. Integration of sustainability principles in the agile project management

By analyzing the percentages of integration of all sustainability principles in management phases, it is concluded (Figure 5) that the principle of interest of stakeholders was the most integrated (over 50% in all phases), followed by the principle of participation of stakeholders (46.2% and more). Digital transformation projects are mostly agile. And, today, organizations are extremely interested in encompassing sustainability principles into their business environment. Therefore, it can be concluded that in all phases of managing these projects, it is of great importance to ensure the support of stakeholders.

5. Conclusion

By committing to operating sustainably and implementing sustainable development strategies through their business goals, plans, and activities, organizations are satisfying the needs, demands, and expectations of stakeholders today while protecting different natural resources for the future. For organizations that have joined this global business trend, one of the benefits is certainly the achievement of a competitive advantage, which is especially valued by stakeholders. Today, competitive advantage, regardless of industry and sector, is achieved through the digital transformation of business (Kraus et al., 2021). The role of stakeholders in that process is extremely important, so it is necessary to take care of their interest and participation (Toljaga-Nikolić, 2022). According to Zaoui and Souissi (2020), digital transformation has a strategic, multidimensional, and multidisciplinary character. Bearing in mind the importance of involving stakeholders for the successful digital transformation of business, it can be concluded that agile management integrated with the concept of sustainability can significantly contribute to the success of digital transformation projects. The research results showed that agile management is open to supporting the integration of sustainability principles, especially those concerning stakeholders. In the research sample, projects from the IT industry dominated, which can be seen as a limitation. Concerning that the application of agile project management has gone beyond the scope of the IT industry and that digital transformation has encompassed all spheres of business, future research directions will focus on other industries as well.

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