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Operations Research Implementation in Civil Engineering and Geodesy Academic Studies in the Former Yugoslav Republics

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ABSTRACT

The research presented in this paper is an extension of the research on the implementation of operations research in the subjects of undergraduate (bachelor's) and master's academic studies at the faculties of civil engineering and geodesy. For the purposes of this research, besides the Republic of Serbia, five more countries in the region were included: Bosnia and Herzegovina, Croatia, Slovenia, Montenegro, and the Republic of North Macedonia. A total of fourteen faculties from former Yugoslav countries were analyzed, and all of them are public, except UNION Nikola Tesla. This topic emphasizes the importance of implementing operations research in civil engineering and geodesy subjects as a mathematical method of decision-making.

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1. Introduction

In Operations research is a field of applied mathematics that integrates advanced analytics methods to improve management and decision-making (Vasegaard, 2021; Bakary et al., 2026). Moreover, mathematical tools are used not only to investigate mathematics further, but rather to build mathematical models, analyze complex situations, and solve problems within the operations research domains (Stonybrook, 2025; Fujita et al., 2025; Mitrovic et al., 2025). Its historical origins are in the 17th century (Vasegaard, 2021) when mathematicians Blaise Pascal and Christiaan Huygens solved problems involving complex decisions (the problem of points - a classical problem in probability theory) by using game-theoretic ideas and expected values, while Pierre de Fermat and Jacob Bernoulli solved these types of problems using combinatorial reasoning instead. The modern version of operations research dates back to World War II, when scientists and mathematicians were recruited to solve complex military problems such as critical logistics and supply chain issues. In 1938, the term operations research was used for the first time by a group of British Royal Air Force officers and civilian scientists who were asked to determine how recently developed radar technology could be integrated into the wider air defense network (Assad, 2011).

In 1947, an American mathematician George B. Dantzig created the first mathematical technique of operations research, called the Simplex Method, which greatly simplified the solution of linear programming problems (University, 2025). According to C. Goodeve (Goodeve, 1948) the operations research represents a scientific method for providing executive departments with a quantitative basis for decisions regarding the operations under their control.

The purpose of operations research is to translate complicated, but important real-world problems into precise, quantitative language that can be clearly and unambiguously analyzed (Rajgopal, 2025). According to (Gupta, 2019), the operations research development stages consist of the following six sequential steps: (i) Observation of the problematic setting and the problem formulation; (ii) Creating a model; (iii) Deriving the solution from the model; (iv) Testing the model and its solution as well as updating the model; (v) Establishing control over the solution, and (vi) Implementation of the final results. In order to optimize and improve decision-making processes different techniques can be used (Kapadi, 2022), such as: linear programming, non-linear programming, integer programming, decision theory, queuing theory, game theory, network scheduling, information theory, Markov Process, simulation, etc. Today, operations research has a wide range of applications such as in industries, from telecommunication to health care to financial services, facilities planning, manufacturing, the construction sector, marketing, human resources, etc. Therefore, Alex Elkjær Vasegaard (Vasegaard, 2021) tried to illustrate the complexity of operations research in terms of the related fields, subfields, and the addressed problems, although he was limited to a 2D representation as there were many other connections between disciplines, e.g. probability theory and statistics are integral to machine learning (ML), Figure 1. Furthermore, artificial intelligence (AI), defined as machine capacity to carry out operations that ordinarily require human intellect, and ML, as a branch of AI that focuses on developing algorithms that learn from data and experience, have become essential tools for advancing operations research (Soori, 2023). AI techniques have shown great potential in improving every stage of the operations research process.

Figure 1. 2D holistic illustration of the disciplines and problems related to operations research (Vasegaard, 2021)

In this paper are presented the research about the implementation of operations research in subjects at civil engineering and geodesy undergraduate and master academic studies in former Yugoslav republics.

2. Methodology

Operations research techniques are frequently required in engineering design, where formulating a design task as an optimization problem—without imposed economic or technical constraints—often results in multiple feasible solutions. Although these methods were initially created to address managerial and operational challenges in established systems, they are also well-suited for application in various engineering design scenarios. This is the reason why it is important to implement operations research in the engineering study programmes.

Applying Operations research, also referred to as Management Science is the application of a scientific approach to solving difficult resource allocation, management and engineering problems in order to make

better decisions. Operations research has applications in many fields, including civil and environmental engineering (Jaynes, 1957). There are ways to combat modeling limitations and data quality issues, but it is the responsibility of the operations research analyst to incorporate any limitations or assumptions into their analysis. Operations research tools should not be treated as a black box from which results are implemented without question, interpretation and context are vital to their successful application.

There is established EURO Working Group "Operations Research in Sustainable Development and Civil Engineering". This idea was taken (Lownes, 2023) after a long international collaboration between researchers from several European countries (Lithuania, Germany, Poland, United Kingdom, Belgium, Denmark, Latvia, Estonia, Czech Republic, Slovenia). The working group was created at EURO Conference XXIII in 2009, Bonn (Germany). In the 2013, in this group were more than 100 scientists from 20 countries (Lithuania, Germany, Poland, United Kingdom, Belgium, Denmark, Netherlands, Portugal, Latvia, Estonia, Czech Republic, Slovenia, Russia, Ukraine, Australia, Iran, USA, Taiwan and others), but at the early beginning research group consisted of the professors from the only Lithuanian, German and Polish academic and research centers. Marking the importance and the uniqueness of the beginning of collaboration this research group was later in articles referred to as the "scientific triangle".

This article is written on the foundation of former research. The former research was all about civil engineering faculties and investigation of operations research subjects at the faculties. Because of the importance of operations research in engineering studies, the research is updated with analysis of civil engineering curriculums for any changes and geodesy curriculums at the same Universities.

The implementation of operations research in civil engineering and geodesy is a need for the future, and because of that, the scope of this research is defined. The scope is to find out more about the inclusion of operations analysis and research in subjects at the Faculty of Civil Engineering and Geodesy in the former Yugoslav republics. The selection of public faculties includes one private faculty. The faculties of civil engineering and geodesy in six countries are targeted, and the curriculum of every faculty is analyzed.

In the Republic of Serbia, faculties of civil engineering in Novi Sad, Belgrade, Subotica and Niš are selected. Geodesy faculties in the Republic of Serbia are in Novi Sad, Belgrade and Subotica. There is no geodesy study programme in Niš and Novi Pazar. The one private Faculty in Belgrade is also analyzed for civil engineering studies. In Slovenia the Faculty of Civil Engineering and Geodesy in Ljubljana is analyzed. In Montenegro the Faculty of Civil Engineering in Podgorica is analyzed and geodesy study programme at the private Faculty of Applied Sciences. In Croatia, the Faculty of Civil Engineering and Faculty Geodesy in Zagreb are selected. In the Republic of North Macedonia, the Faculty of Civil Engineering in Skopje, is also selected. After detailed analysis of the curriculum of undergraduate (bachelor) studies and master studies at the selected Universities the results are summarized in Table 1.

At the Department of Civil Engineering and Geodesy in Novi Sad, there is one subject, at the 5th year of studies (1st year od master studies) called The modelling of the processes in the civil engineering. This subject is mandatory and carries three ECTS. Also, at the geodesy study programme there is one subject called The methods of optimization. This subject is mandatory and carries six ECTS.

At the Faculty of Civil Engineering in Belgrade, there is one subject at the 3rd year of undergraduate (bachelor) studies called Informational modelling of civil engineering objects and one at the 5th year called Operations research. These subjects are optional and carries four ECTS.

At the Faculty of Civil Engineering UNION Nikola Tesla, there is one subject at the 5th year of studies (1st year of master studies) called Operational Research. This subject is optional and carries five ECTS.

At the Faculty of Civil Engineering and Architecture in Niš, there is no subject in curriculum with operations research involved.

At the Faculty of Civil Engineering in Subotica, there is one subject at the 2nd year of undergraduate (bachelor) studies called The basics of programming. This subject is optional and carries seven ECTS.

At the State University of Novi Pazar, there is no subject in curriculum with operations research involved.

At the Faculty of Architecture, Civil Engineering and Geodesy in Banja Luka, there is one subject at the 5th year of studies (1st year of master studies) called The operational research in civil engineering. This subject is optional and wears four ECTS.

At the Faculty of Civil Engineering in Sarajevo, there is no subject in curriculum with operations research involved.

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited. (Style OREL table title)

City	Faculty	Study Programme	Year	Subject	SCORE (ECTS)
Novi Sad	Faculty of Technical Sciences (Department of Civil Engineering and Geodesy)	Civil engineering	5th	The modelling of the processes in the civil engineering	3
		Geodesy	3rd	The methods of optimization	6
Belgrade	Faculty of Civil Engineering	Civil engineering	3rd	Informational modelling of civil engineering objects	4
			5th	Operations research	4
		Geodesy	-	No subject	-
Belgrade	UNION NikolaTesla	Civil engineering	5th	Operational research	5
Niš	Faculty of Civil Engineering and Architecture	Civil engineering	-	No subject	-
Subotica	Faculty of Civil Engineering Subotica	Civil engineering	2nd	The basics of programming	7
		Geodesy	-	No subject	-
Novi Pazar	State University of Novi Pazar	Civil engineering	-	No subject	-
Podgorica	Faculty of Civil Engineering	Civil engineering	-	No subject	-
Podgorica	Faculty of applied science	Geodesy	-	No subject	-
Banja Luka	Faculty of Architecture, Civil Engineering and Geodesy	Civil engineering	5th	The operational research in civil engineering	4
		Geodesy	-	No subject	-
Sarajevo	Faculty of Civil Engineering	Civil engineering	-	No subject	-
		Geodesy	-	No subject	-
Ljubljana	Faculty of Civil and Geodetic Engineering	Civil engineering	3rd	Project Management	4
		Geodesy	1st	Observations analysis in surveying	4
Zagreb	Faculty of Civil Engineering	Civil engineering	-	No subject	-
Zagreb	Faculty of Geodesy	Geodesy	-	No subject	-
Skopje	Faculty of Civil Engineering	Civil engineering	3rd	Management in civil engineering	5
City	Faculty	Study Programme	Year	Subject	SCORE (ECTS)
Novi Sad	Faculty of Technical Sciences (Department of Civil Engineering and Geodesy)	Civil engineering	5th	The modelling of the processes in the civil engineering	3

At the Faculty of Civil Engineering in Podgorica, there is no subject in curriculum with operations research involved.

At the Faculty of Civil and Geodetic Engineering in Ljubljana, there is one subject at the 3rd year of undergraduate (bachelor) studies called Project Management and also Observations analysis in surveying. The first subject is optional and carries four ECTS. The second subject is mandatory and carries four ECTS.

At the Faculty of Civil Engineering in Zagreb, there is no subject in curriculum with operations research involved.

At the Faculty of Civil Engineering in Skopje, there is one subject at the 3rd year of studies (1st year of master studies) called Management in civil engineering. This subject is optional and carries five ECTS.

Except at the Department for Civil Engineering and Geodesy (Faculty of Technical Sciences, University of Novi Sad), there are no subjects about operations research at the other faculties.

After analyzing the data in Table 1, the conclusion is that at seven faculties of civil engineering in the former Yugoslav republics, subjects connected with operations research are implemented. Five faculties of Civil Engineering do not have subjects on the implementation of operations research. Faculties that have subjects are from: Novi Sad, Belgrade, Subotica, Ljubljana, Skopje, and Banja Luka. Two geodesy faculties which have subjects are the Faculty of Technical Sciences: Department of Civil Engineering and Geodesy in Novi Sad, and the Faculty of Civil and Geodetic Engineering in Ljubljana.

Subjects are mostly optional for Civil Engineering, except for the faculty in Novi Sad. The years in which these subjects are included are the second and third in Skopje, Ljubljana, Belgrade, and Subotica. In Novi Sad, Banja Luka, Belgrade and UNION Nikola Tesla, there are subjects at the master's studies. For geodesy studies at the Department of Civil Engineering and Geodesy in Novi Sad, the subject is obligatory and it is in the third year of studies, first year at the Faculty of Civil and Geodetic Engineering in Ljubljana.

3. Conclusion

Operations Research, also referred to as Management Science, is the application of a scientific approach to solving difficult resource allocation, management and engineering problems in order to make better decisions.

In this work the inclusion of operations research in curriculum of civil engineering and geodesy faculties is analyzed. Six countries from region are selected: Serbia, Bosnia and Herzegovina, Croatia, Montenegro, Republic of North Macedonia and Slovenia. In that six countries fourteen faculties are selected for research. After detailed analyze of curriculums the results show that at five faculties of Civil Engineering do not have subjects on the implementation of operations research. Faculties that have the subjects are from: Novi Sad, Belgrade, Subotica, Ljubljana, Skopje and Banja Luka. Subjects are mostly optional, except for the Faculty of Technical Sciences in Novi Sad. Two geodesy faculties which have the subjects are the Department of Civil Engineering and Geodesy in Novi Sad and the Faculty of Civil and Geodetic Engineering in Ljubljana.

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