TÜRKIYE CUMHURIYETI'NIN YÜZÜNCÜ YILI

Sustainable Transportation Systems in Civil Engineering and Managerial Informatics Assessments in Construction Systems

Editor
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Editor: Doç. Dr. Atila KUMBASAROĞLU

ISBN: 978-625-6707-52-8

Page Layout: Gözde YÜCEL

1st Edition:

Publication Date: 25.12.2023

BIDGE Publications

Certificate No: 71374

www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com

Krc Bilişim Ticaret ve Organizasyon Ltd. Şti.
Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

Preface

Depending on today's developing technology, sustainable transportation systems in Civil Engineering and management informatics in construction systems have actually become one of the key concepts of the 21st century. This concept has become indispensable, especially as the academic community has realized that conventional planning methods had negative consequences on the environment, such as pollution and the excessive use of natural resources. Naturally, professionals specializing in different engineering fields had decided to improve planning methods in order to avoid future generations from focusing on finding solutions to the problems caused by conventional planning.

To achieve a sustainable community, changes in transportation systems in Civil Engineering and management informatics in construction systems are required.

Within the scope of this book, innovative issues such as Buıldıng Sustaınable Roads: Investıgatıon Of Earth Roads On Transportatıon Engıneerıng, A TOPSIS-Based Evaluation of Urban Transportation and Supermarket Accessibility: A Case Study of Konyaaltı in Antalya, Frame System Analysis with Stochastic Finite Element Method, Consultancy And Owner Representatıon Servıce In Constructıon Management, Building Through Crisis: The Impact Of Covid-19 On Civil Engineering Practices And Perspectives, and Using Pumice at Road Pavement Construction in Different Aspects were mentioned.

We would like to thank all the authors who contributed to the arrangement and publication of the book, especially **BIDGE PUBLICATIONS**.

Editor

Doç. Dr. Atila KUMBASAROĞLU

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CHAPTER I

Buıldıng Sustaınable Roads: Investıgatıon Of Earth Roads On Transportatıon Engıneerıng

Nuriye KABAKUŞ[1]
Yeşim TARHAN[2]

Introduction

With the rapid development of technology, road transportation networks are expanding globally day by day. However, the use of petroleum-based asphalt and cement-based concrete as road superstructure materials has significantly increased the carbon footprint, leading to global climate change. Moreover, the production and maintenance of roads made with these materials are costly, negatively affecting the economy of countries. In response, the construction sector is looking for sustainable and eco-friendly

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alternatives to these materials. This study proposes earth roads as a viable alternative to asphalt and concrete. In road engineering, strength, durability, comfort, safety, and economy are the fundamental principles for pavement selection. This article emphasizes the importance of selecting materials that align with these principles to create sustainable roads. It investigates the use of environmentally friendly earth roads made with natural materials and provides recommendations for their widespread use. While high-strength road pavements are mandatory in some areas due to population growth and increased motor vehicle use, stabilizing earth-based materials and using new-generation earth roads can significantly contribute to a country's economy. This study highlights the potential benefits of using earth-based materials for road construction and offers solutions to improve sustainability in the transportation sector.

Development of Earth-Based Materials

The use of earth-based materials dates back thousands of years, with evidence of their use in ancient civilizations such as those in Mesopotamia, Egypt, and China. However, it wasn't until the 20th century that earth-based materials started to gain recognition as a sustainable and affordable alternative to traditional building materials. Earth-based materials have several advantages in construction. They are often readily available and cost-effective, making them an attractive option for many construction projects (Pacheco-Torgal and Jalali, 2012). Earth-based materials also have excellent thermal mass properties, providing natural insulation and making buildings more energy-efficient (Alassaad et al., 2021). Additionally, these materials are recyclable, reducing waste and helping to protect the environment. Overall, the use of earth-based materials in construction can have a lower environmental impact than traditional building materials (Stanislas et al., 2021).

One of the key developments in the use of earth-based materials came with the emergence of rammed earth construction, which involves compressing earth into a durable, load-bearing structure. There are many construction techniques using earth in the construction sector. Examples of these are Adobe (Adobe, Mudbrick, Cob), Bulk Earth Technique, Rammed Earth Technique, Compressed Earth Block Masonry Technique, and Wattle and daub Technique (Koç and Akbulut, 2017; Damme and Houben, 2018).

It is clear that there is a need for an improved earth-based blend that seamlessly merges fast texturing with early strength. By incorporating scientific knowledge and expertise from the concrete industry into soil construction, significant economic and environmental benefits can be achieved (Ouellet-Plamondon et al., 2015). By surpassing the current limitations of earth-based construction materials, we can enhance their usefulness in modern construction while simultaneously minimizing the environmental impact of the construction industry.

Earth-based materials are commonly utilized in transportation structures, with earth roads being one of the oldest transportation routes used by humans for thousands of years. The development process of these roads has gone through various stages throughout history.

The Evolution of Earth Roads: A Journey Through History

In ancient times, people used to traverse on foot or the backs of animals, following the natural paths that existed. However, as civilization progressed, the need for better transportation routes became evident, leading to the commencement of the construction of earth roads.

The development process of earth roads is shown in Figure 1.

Figure 1: Development of earth roads. a, b Examples of "Macadam Roads", c: crushed stone road bonded with gravel, d: roller compacted earth road. (Lay, 2009, Anonymous 2023).

The first civilizations: With the emergence of the first civilizations, the construction of earth roads further developed. For example, during the construction of the pyramids in Egypt, stone and sand roads needed to be built. In addition, mud bricks developed by the Sumerians were used in the construction of earth roads. (Arnold 1991; Ching et al., 2017)

The Roman Empire: During the Roman Empire period, the construction of earth roads reached an important stage. The Roman Empire had the most advanced road network in world history. Roman roads were constructed as paved roads with a smooth surface (Van Tilburg 2007; Hitchner 2012).

The New World: With the discovery of the New World, the construction of earth roads further developed. In the first travels from Europe to America, the paths opened by the indigenous people were used. Later, the construction of sandy earth roads began in America for the first time. (Stannard 1993; Merrell 2012).

The Industrial Revolution: With the Industrial Revolution, the construction of earth roads further developed. The Industrial Revolution caused the materials used in road construction to diversify. For the first time, limestone, coal tar, and asphalt began to be used (Waters and Zalasiewicz, 2018; Bitumen. 1995)

Modern Period: Today, the construction of earth roads is carried out with modern technological tools. Materials used in road construction offer various options such as asphalt, concrete, and stone pavements (Lay, 2009). The choice of material depends on the road's class, standard, expected traffic volume, and location. Engineers and construction professionals evaluate and decide on the most suitable material to use based on the road's requirements and other factors such as the climate and topography of the area. This ensures the durability and longevity of the earth-road.

Earth Road Construction Techniques

Earth road construction techniques refer to the methods used to build roads using natural soil materials. These techniques involve the use of soil stabilization methods to enhance the engineering properties of the soil and ensure its suitability for road construction. The most common soil stabilization techniques used in earth road construction include adding chemical stabilizers, such as lime and cement, to the soil, and incorporating other materials, such as gravel, sand, and crushed stones, to improve the soil's load-bearing capacity, stability, and durability (Kézdi, 2016).

The construction process of an earth road typically involves the site preparation, grading, compaction, stabilization, surface preparation, and finishing steps (Mroueh et al., 2001; Jungerius et al., 2002; Kézdi, 2016). Vegetation, rubble, and any other obstacles that may impede the construction process are removed from the site. It is essential to clear the site by sweeping an area that is 25 cm wider than the intended pavement width on both sides (Umar and Ağar, 1991). In road construction, the accuracy of the grading to achieve the desired elevation and slope for the road determines the overall quality of the road by affecting the drainage, stability and smoothness of the road (Sayers, 1998). Appropriate compaction techniques help to increase the density and strength of the road, which can reduce the risk of rutting, deformation, and other types of damage (Wang et al., 2022). The stabilization process involves the use of one or more techniques, such as adding chemical stabilizers like lime and cement to the soil, or incorporating other materials like gravel, sand, and crushed stones to enhance the soil's load-bearing capacity, stability, and durability (Galán-Marín et al., 2010; Al-Naje et al., 2020; Zada et al., 2023). Layers of materials such as gravel, sand and crushed stone are spread and compacted on top of the stabilised soil layer to increase the road surface, durability and load carrying capacity (Aggarwal, 2012; Péterfalvi et al., 2015). After surface preparation, the construction of a earth road should ensure adequate geometrical straightness and surface roughness of the road. The finishing layer may consist of materials such as gravel, sand or other aggregates, depending on the desired texture and appearance of the road surface.

Earth road construction techniques are widely used in rural areas and developing countries where the cost of conventional road construction methods is prohibitively high (Fukubayashi and Kimura, 2014).

A Look at Stabilization Methods

Earth-based materials stabilization techniques are used in road construction to improve the properties of natural soil materials and make them suitable for use in the construction of durable and resilient roads. These techniques include mechanical, thermal, biological, and chemical stabilization, which are used to increase the soil's strength and durability. Mechanical stabilization involves the use of equipment and machinery to compact and densify the soil, while thermal stabilization utilizes heat to modify the soil's properties.

Mechanical stabilization is a road construction technique that involves using heavy equipment to lay and compact a well-graded aggregate on the road. The aggregate is carefully selected to meet certain physical conditions and has an optimum water content. The equipment is then used to compact and densify the soil, which helps to increase its load-bearing capacity, stability, and durability (Tunç, 2001). Mechanical stabilization is a widely used technique in earth road construction due to its effectiveness in improving soil properties and its cost-effectiveness compared to other stabilization methods (Elias et al., 2009).

Thermal stabilisation involves the use of heat to improve the properties of the soil by heating the soil to a temperature above its normal range, causing changes in its chemical and physical properties and thus increasing its load-carrying capacity, stability and durability (Afrin, 2017). This method is widely used for road construction in areas with high moisture content or cold weather conditions where the soil is susceptible to frost heave or damage from freeze-thaw cycles. The heat source can be provided by various methods, such as steam, hot air or infrared radiation. The thermal stabilisation technique is effective in improving soil properties, but can be expensive and time consuming compared to other stabilisation methods (Moiseev et al., 2023).

Biological stabilization is a sustainable and eco-friendly technique that utilizes microorganisms such as bacteria, fungi, and enzymes to improve the engineering properties of the soil. The microorganisms help to break down organic matter and produce byproducts that can bind soil particles together, thereby enhancing its strength, stability, and load-bearing capacity (Lim et al., 2014). This method can be effective in improving the soil's properties in a natural and environmentally friendly way, and it is commonly used in soil remediation and ecological restoration projects (Ramdas et al. 2021).

Chemical stabilization is a process of improving soil properties through the use of chemical additives such as lime, cement, fly ash, clay, geosynthetics and bitumen (Zada et al., 2023). It is carried out to increase the resistance of earth roads to maintain their stability and load-bearing capacity under different weather and traffic conditions (Das, 2003). The addition of these chemicals enhances the soil's strength, durability, and water resistance properties, making it suitable for construction purposes. Proper selection of the chemical additive and adequate mixing and compaction are necessary to ensure the success of chemical stabilization (Ismaiel, 2006; Cabezas and Cataldo, 2019). Although natural soil-based materials have their limitations as road superstructure materials, they can be enhanced with a suitable binder to create a new generation of eco-friendly and cost-effective coating material. With the rise of geopolymer concrete technology, it is believed that a matrix made of a geopolymer, and soil mixture could potentially rival traditional asphalt and concrete options. By exploring and developing innovative ways to stabilize earth-based materials, we can reduce our carbon footprint and promote sustainable practices in the construction industry.

Areas of Use of Earth Roads

Earth roads are frequently used, especially in rural areas where paved roads are not feasible due to cost or terrain constraints. In regions with challenging terrains, such as mountainous or desert areas, earth roads are often the only viable option for transportation. Despite their rough surfaces and limited durability compared to paved roads, earth roads remain an important means of accessing remote areas and supporting activities such as agriculture, mining, and conservation efforts.

Agricultural lands are often surrounded by earth roads, and it is important to have earth roads for farmers to access with their tractors and other farming equipment (Kézdi, 2016; Howe et al., 2019). Trails found in forests require the use of earth roads for forest workers and off-road vehicles. Mining areas are usually located in areas with difficult terrain, and mining companies build earth roads to transport machinery and vehicles (Kézdi, 2016). Many roads leading to natural parks and conservation areas are earth roads for the preservation of wildlife and natural habitats (Schonewald-Cox et al., 1992). Construction projects are typically located in areas with difficult terrain, and as a result, construction companies build earth roads to transport materials and heavy machinery (Forman et al., 2003). Rural village roads are often made of earth, providing access for villagers to their homes, schools, and other areas (Howe et al., 2019).

Advantages and Challenges of Earth Roads

Pavements used in highway superstructures are expected to fulfill two basic functions. These are to provide the necessary comfort and safety for vehicles and to have sufficient stability against the stresses caused by the loads on them. The type of pavement (flexible and rigid) is selected depending on the traffic volume and composition, total equivalent axle load, climate, and environmental conditions (Tunç, 2001). Flexible pavements are divided into two categories as low and high-standard pavements. On low-traffic volume roads, pavements that do not require low-quality materials and advanced technology are both economical and easy to construct. Earth roads fall into this category of low-standard roads. Earth roads are generally cheaper to construct and maintain than asphalt roads, making them a more cost-effective option for rural or remote areas with limited budgets.

Traffic and service roads on earth roads can be kept open during maintenance and repair activities, as long as the work zones are properly marked and traffic is directed accordingly. This helps minimize disruptions to local communities and the transportation network while allowing maintenance and repair activities to be carried out in a timely and efficient manner (Tunç, 2001).

The construction of earth roads often involves a phased construction process that allows for flexibility in adjusting the thickness and quality of the pavement to accommodate increasing traffic density over time. This is possible due to the ability to add layers of materials to the road surface without the need for complete reconstruction. As traffic density increases, additional layers of materials can be added to the road surface to increase its strength and durability (Qiao, 2020).

Earth roads typically require fewer resources and materials during construction, which results in a lower carbon footprint. Additionally, the use of earth-based materials in road construction can reduce the need for resource-intensive materials like concrete and asphalt, which are non-renewable resources. Earth roads also have a lower impact on natural habitats and ecosystems, as they allow for more natural water infiltration and drainage, reducing the risk of erosion and runoff (Huang and Zammataro, 2013; Melanta et al., 2013; Balaguera et al., 2018).

Earth roads absorb less heat than asphalt or concrete roads, which reduces the heat island effect in urban areas. This effect can contribute to urban heatwaves and other environmental issues (Mohajerani and Jeffrey-Bailey 2017; Ibrahim et al., 2018).

Earth roads are also of great importance as they can be constructed quickly and easily and can be quickly adapted to the changing conditions of existing road networks. Earth roads contribute greatly to a sustainable environment as they are designed and constructed in a way that minimizes their impact on the environment. In addition to these advantages, earth roads also have disadvantages.

Earth roads require more maintenance than paved roads, as their surfaces can become rutted or eroded over time. They may need to be graded or filled in to maintain a smooth surface for vehicles (Skorseth, 2000).

Earth roads are particularly vulnerable to weather conditions, such as heavy rain or snow, which can make them impassable or dangerous to travel on (Forman, 2003). In some cases, flooding or landslides can even wash out entire sections of an earth road, making it unusable until repairs are made.

Earth roads can generate significant amounts of dust, which can be a nuisance for drivers and nearby residents (Skorseth, 2000). This can be particularly problematic in dry, arid regions where dust storms are common.

Earth roads may not be accessible for certain types of vehicles, particularly those with low ground clearance or that are not equipped for off-road driving. This can limit access to remote areas and make it difficult to transport goods or people (Porter, 2002).

Earth roads can be less safe than paved roads, particularly at night or in poor weather conditions. They may not have reflective markings or other safety features, and their uneven surfaces can make it more difficult to control a vehicle or avoid obstacles (Zhang et al., 2023).

Earth roads can have a significant impact on the environment, particularly in areas with sensitive ecosystems. They can cause erosion, habitat fragmentation, and soil compaction, which can harm plants and wildlife (Trombulak and Frissell, 2000; Coffin, 2007)

Earth roads cannot provide the high strength and comfort of high-standard roads. Therefore, durability and operating costs are among the weaknesses of Earth roads.

Future Work on Earth Roads

In the future, the importance of earth roads as environmentally friendly road surfacing will continue to increase. This will occur as environmentally friendly and sustainable road construction becomes increasingly important. Earth roads require less resource consumption and have less environmental impact compared to other road construction techniques as they are made using natural materials. Additionally, the natural structure of earth roads allows for increased water permeability, allowing surface water to return to underground sources. Due to these features, earth roads will become more widespread as an environmentally friendly roads surfacing in the future.

Recommendations for the widespread use of earth roads as an environmentally friendly pavement:

Improving road quality by using new generation road technologies to ensure adequate stability and durability, and maintenance and improvement of existing earth roads with these technologies.

For earth roads, stabilization methods, dust control measures and the use of environmentally friendly building materials can make the road pavement more durable, safe, and comfortable.

The safety of earth roads can be improved by using appropriate signage, increasing the number of reflectors, and other safety measures.

Appropriate land use and planning in the construction of new roads can contribute to a sustainable environment by protecting the environment and natural resources.

Accessibility between transportation modes can be facilitated by integrating earth roads with other transportation systems.

Since earth roads are an important option for countries to achieve their sustainability goals, cooperation with local governments can be established. In addition, seminars and training can be organized to inform and raise awareness of local governments and investors about the advantages of earth roads.

Contribute to the national economy by preferring new generation earth roads instead of bituminous pavements, which increase our foreign dependency. The carbon footprint can be reduced by using less fuel and material resources in the construction of earth roads.

Conclusion

Road transport investments are crucial for economic growth and development; while asphalt roads are widely used in many countries, earth roads continue to be used in rural areas and developing countries. Therefore, understanding the use and importance of earth roads is important for effective transport planning and management. This study explores the historical and current importance of earth roads, focusing on their role in providing access to remote areas and supporting rural economies.

The use of earth roads should be encouraged through various policies and initiatives due to their sustainable environmental impact. Countries should invest in research and development to improve the engineering properties of earth materials and stabilisation techniques. Because the low construction and maintenance cost, which is one of the main advantages of earth roads, will make a great contribution to the economy of especially undeveloped and developing countries.

Demand for earth roads should be increased and a new generation of materials for earth roads should be developed, which will lead to the development of a more sustainable and environmentally friendly construction sector.

Today, asphalt and concrete materials, which are widely used in road construction, consist of petroleum-derived and energy-embodied materials. However, earth roads are made of materials obtained from natural materials whose environmental and economic benefits are countless. The widespread use of earth roads on roads with low traffic volumes is important for a sustainable future and a more livable environment for countries. Challenges of soil-based materials should be eliminated with various engineering approaches, and new-generation road materials should be produced by improving their technical properties.

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CHAPTER II

A TOPSIS-Based Evaluation of Urban Transportation and Supermarket Accessibility: A Case Study of Konyaaltı in Antalya

Emre DEMİR[1]

Introduction

Urban transportation and its development, including its infrastructure, play pivotal roles in shaping the accessibility and functionality of various amenities within a city. In this manner, supermarkets stand as critical components of urban living, influencing a community's quality of life and economic vitality. As urban populations and the need for transportation grow, the efficient and equitable provision of transportation services to connect residents with supermarkets becomes increasingly crucial. Recognizing this imperative, this study investigates the complicated

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relationship between transportation attributes and supermarket accessibility. A case study is conducted for this research within the districts of the Konyaaltı municipality in Antalya.

The motivation behind this research stems from the growing significance of sustainable urban transportation and planning, where integrating efficient transportation systems with essential amenities like supermarkets is vital for fostering accessible urban spaces. In many urban transportation contexts, the decision-making process related to the placement and accessibility of supermarkets lacks a systematic evaluation method that incorporates key transportation attributes. To address this gap, this study employs the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a robust Multi-Criteria Decision-Making (MCDM) technique. By doing this, we assess and rank the districts of Konyaaltı municipality based on their transportation features and supermarket accessibility for the first time.

The scope of this study encompasses the 39 districts within Konyaaltı municipality, each representing a unique urban fabric with diverse transportation characteristics. Our focus lies on four key evaluation criteria: 1) Traffic quantity in the district, 2) Road network density in the district, 3) Public transportation service in the district, and 4) Supermarket quantity in the district. These criteria are meticulously chosen to capture the nuanced relationship between transportation attributes and supermarket accessibility, providing a comprehensive framework for district ranking.

This research has significant implications for urban transportation authorities, policymakers, and residents. By evaluating and ranking districts based on their transportation features and supermarket accessibility, we aim to contribute valuable insights that can optimize transportation systems, inform transportation interventions, and enhance the overall urban transportation and living experience. The findings of this study also pave the way for a more sustainable and equitable distribution of crucial amenities, aligning with the broader goals of urban development and its transportation system.

In the following sections, a literature review is introduced, and the methodology employed is presented. Later, we provide the application and examine the results obtained. Moreover, a comprehensive discussion of the application of the findings is submitted.

Literature Review

TOPSIS, introduced by Hwang and Yoon in 1980, stands as an MCDM method with widespread applications across diverse fields (Yoon & Hwang, 1980). Its adaptable applications include selection of staff, appraisal and selection of suppliers, location choice, mineral potential mapping in mineral deposits, and picking industrial robots (Nabeeh et al., 2019; Guo et al., 2021). In the complex process of evaluating alternatives or decision options, TOPSIS builds upon two fundamental themes: the optimal solutions that are positive and negative. The technique's primary objective is to identify the alternative choice that is the closest to the positive ideal scenario and the furthest away from the negative optimal outcome. In essence, TOPSIS exposes not just distances to positive and negative optimal options, but also ideal and non-ideal solutions. Moreover, we need to emphasize that the TOPSIS methodology necessitates at least two decision options for application. TOPSIS is distinguished by its basic analysis approach, which lacks sophisticated algorithms and mathematical models. This characteristic, coupled with its ease of use and relatively straightforward interpretation of application outputs, renders TOPSIS applicable in numerous fields. Its adaptability and practicality make TOPSIS a preferred choice for decision-makers across various disciplines (Yoon & Hwang, 1980).

TOPSIS finds extensive applications in transportation systems and urban transportation planning, contributing to informed decision-making processes. In evaluating urban transportation projects, diverse criteria, such as cost-effectiveness, environmental impact, accessibility, and safety, are considered (Gumus, 2009; Awasthi, Chauhan & Omrani, 2011; Djordjević & Krmac, 2019). Decision-makers assign weights to these criteria, facilitating the identification of optimal transportation system implementations. Furthermore, the adaptability of TOPSIS extends to optimizing bus or tram routes, incorporating criteria like travel time, passenger capacity, environmental impact, and cost to identify the most efficient routes (Soltani, Marandi & Ivaki, 2013; Micale et al., 2019). In the area of traffic management, TOPSIS aids in the selection and prioritization of strategies by considering criteria such as traffic flow improvement, congestion reduction, and environmental impact minimization, thereby enhancing traffic control and management in urban areas (Zhang et al., 2018; Li et al., 2019). This multifaceted utility puts TOPSIS as a valuable tool in addressing the complexities of modern urban transportation challenges.

TOPSIS emerges as a pivotal tool in numerous studies on cities, districts, and neighborhoods, offering deep insights into complicated decision-making processes. The method's application extends to the detailed selection of optimal locations for new infrastructure, public spaces, and commercial developments, thereby bolstering urban services and sustainability (Guo & Zhao, 2015; Luan et al., 2019). In urban planning and development, TOPSIS integrates diverse criteria such as accessibility, environmental impact, economic feasibility, technology integration, and energy efficiency, offering a comprehensive approach to decision-making (Sindhu, Nehra & Luthra, 2017). Additionally, TOPSIS plays a crucial role in evaluating the environmental impact of urban projects or policies, assessing alternatives based on criteria encompassing air and water quality, green space preservation, and overall ecological sustainability (Dang, Wang & Dang, 2019; Luan et al., 2019; Foroozesh et al. 2022).

Methodology

The algorithmic steps of the TOPSIS method are provided below (Yoon & Hwang, 1980).

Step-1: A decision matrix is created.

The decision matrix is an n x m dimensional matrix produced by the decision maker after identifying the alternatives and assessment criteria. Here, n and m are the numbers of choice options and evaluation measures, respectively.

Step-2: Standard decision matrix which is normalized or regulated matrix is formed.

The standard decision matrix is acquired by computing the square root of the sum of squares of the values of each measure of the decision matrix (sum of squares of the column values) and dividing the relevant component of the column by this value. If the value of any element of the choice matrix is 0, the value of the relevant section in the standard decision matrix is also 0.

Step-3: A weighted standard decision matrix is established.

Initially, the weight standards for the assessment criteria are determined. Here, the sum of all weights must be the value of 1. This weighting approach exposes the subjective characteristic of the TOPSIS in decision-making since the weighting process is based on the importance or significance of the criteria. The components of the standard decision matrix are multiplied by their respective weight values to form a matrix called weighted standard decision matrix.

Step-4: Obtain positive ideal and negative ideal or optimum solution values.

By means of the weighted standard decision matrix, the sets of positive ideal and negative ideal solutions are obtained for each criterion consistent with the objective of the evaluation criterion of interest. If the evaluation criteria are in terms of benefits, the positive ideal solution is the largest value of the columns of the weighted standard decision matrix, and the negative ideal solution is the smallest value of the columns of the weighted standard decision matrix. If the appraisal criteria are in terms of costs, the positive ideal outcome is the smallest value of the columns of the weighted standard decision matrix, and the negative ideal answer is the largest value of the columns of the weighted standard decision matrix.

Step-5: The distances to the positive ideal and negative ideal solutions are acquired.

The Euclidean methodology is used to find the deviations of the evaluation criteria for each decision alternative from the positive ideal and negative ideal solution values. Accordingly, distances or distance values are computed for the number of decision options.

Step-6: Calculate the relative closeness coefficients to the optimum or ideal solution.

The distances from the positive ideal and negative ideal solutions are accepted to estimate the relative closeness constants of each decision possibility to the ideal result. Relative closeness values are found for each decision option. Further, the share of the distance to the negative ideal answer in the total distance is calculated. Consequently, decision options are prioritized as close to the value of 1.

Application

Evaluation Criterion 1 (EC1): Traffic Quantity

Urban areas with larger populations tend to attract more economic activities, businesses, and job opportunities. Attraction to them can lead to increased commuting as people travel between home to work and work to home, contributing to overall traffic quantity. In densely populated urban areas, there is typically a higher demand for transportation services, leading to increased vehicle ownership and usage. This surge in vehicular activity contributes to traffic congestion (Chang et al., 2021).

Traffic quantity is deemed an undesirable parameter for evaluation within the scope of this study. While it is feasible to procure data about traffic density within districts, it is noteworthy that population density typically manifests a visible correlation with traffic volume. Consequently, in the present investigation, the demographic composition of districts is posited to serve as an indicative representation for assessing traffic quantity within the respective regions (Kenworthy & Laube, 1999; Chang et al., 2021).

The utilization of population metrics as a surrogate for evaluating traffic density is grounded in the idea that urban areas with larger populations tend to exhibit increased vehicular activities, resulting in heightened traffic volumes. This correlation is substantiated by various factors, including augmented reliance on private vehicles and escalated commuting patterns associated with increasing economic activities. Therefore, the population data are utilized for this investigation and included in the analysis (TÜİK, 2019). Recognizing population metrics as a surrogate indicator for traffic assessments enhances the realistic alignment of study objectives with the complicated dynamics of urban development. Ultimately, this fosters a more comprehensive understanding of the interaction between demographic trends and vehicular mobility within urban landscapes.

In addition to these mentioned above, high traffic quantity in urban areas impacts consumer convenience and supermarket accessibility (Jaravaza & Chitando, 2013). Districts with lower traffic congestion are likely to provide easier access to supermarkets, making them more attractive to consumers. Besides, supermarkets depend on efficient transportation and accessibility for their operations, including the delivery and transportation of goods. Further, districts with lower traffic quantity offer better logistical efficiency and lower supermarket operational costs. Moreover, consumers often prefer shopping in districts with minimal traffic congestion, as it enhances the overall shopping experience. Supermarkets strategically located in lower-traffic areas attract more customers and foster repeat business. Additionally, high-traffic areas often face challenges related to parking availability. On the other hand, districts with lower traffic quantity are likely to provide better parking options for supermarket customers, positively influencing district choice.

Therefore, the relationship between traffic quantity and district choice for supermarket accessibility influences the weight assigned to each criterion in an MCDM procedure. The importance of traffic-related factors in district choice is a critical consideration. Since decision-makers in urban transportation need to prioritize districts with lower traffic quantity when considering locations for supermarkets, the goal of improving accessibility which is a convenience for consumers is seen.

Evaluation Criterion 2 (EC2): Road Network Density

Road network density is a critical factor influencing transportation, accessibility, and connectivity within urban areas. Districts with a denser road network are likely to offer better transportation links, making supermarkets more accessible to a larger population. Supermarkets in districts with a well-developed road infrastructure can attract more customers due to enhanced convenience in reaching the location. A dense road network facilitates smoother and quicker travel for shoppers. For supermarkets, a dense road network is advantageous for logistics and supply chain management. Efficient road networks enable timely and cost-effective delivery of goods, contributing to the overall operational efficiency of the supermarket (Han et al., 2019). In an MCDM process, the relationship between road network density and district selection for supermarket accessibility influences the weight assigned to each criterion. The importance of road network-related factors in district choice is one of the critical considerations. In an MCDM framework, factors related to the operational efficiency of supermarkets, such as delivery logistics and transportation costs, may be given a high priority.

In this investigation, the road network data is sourced from a publicly available mapping program, specifically Google Maps. Through a meticulous process involving utilizing the mapping program and conducting dedicated analyses, the roads' dimensions, including widths and lengths, are systematically considered. Subsequently, a comparative analysis is undertaken, aligning these road dimensions with the spatial extent of the districts. This comparative evaluation yields a quantitative scale that effectively depicts the road network density within each district. Consequently, the acquired values represent the road network density, quantifying the spatial distribution and intensity of the road infrastructure within the study area.

Evaluation Criterion 3 (EC3): Public Transportation Service

Districts with robust public transportation services offer increased accessibility to a broader demographic. Supermarkets close to public transportation hubs, such as stops and stations, become more accessible to individuals who rely on public transit, expanding the potential customer base. Additionally, areas with reliable public transportation services can reduce the need for individuals to use private vehicles for commuting. Decreasing private vehicle use can relieve traffic quantity and congestion, making it more convenient for shoppers to access supermarkets without the constraints of traffic issues and related problems such as parking. Moreover, public transportation is often associated with sustainability and environmental awareness. Supermarkets in districts with good public transportation services align with sustainable development goals (United Nations, 2023), attracting environmentally conscious customers. In this manner, this study's public transportation service criterion contributes to SDG 11, which makes cities and human settlements such as towns and districts comprehensive, safe, and sustainable. In addition to all these, proximity to public transportation hubs can positively impact the operational logistics of supermarkets. Efficient public transit facilitates the timely delivery of goods, reduces transportation costs, and streamlines the supply chain (Farber, Morang & Widener, 2014; Widener et al., 2015). In an MCDM process, the association between public transportation service and district selection for grocery and market accessibility may influence the weight provided to each criterion. In fact, public transportation service is a crucial element in district choice because the MCDM technique is strongly based on public transportation-related factors.

This study precisely conducts a comprehensive enumeration of bus and tram stops within each district. A comparative scale is derived after obtaining these numerical counts, facilitating a nuanced evaluation of the variations between neighborhoods. This scale is a quantifiable indicator, elucidating the extent and efficacy of public transportation services within each district.

Evaluation Criterion 4 (EC4): Supermarket Quantity

A higher quantity of supermarkets within a district reduces the travel distances for consumers to access grocery stores. Decreasing travel distances improves convenience and accessibility, as shoppers have many nearby options. In addition, districts with more supermarkets offer consumers a greater variety of shopping options. Multiple supermarkets nearby increase consumer choices, meeting diverse preferences and needs. On the other hand, increased competition among supermarkets in a district can lead to competitive pricing and improved services. Consumers benefit from cost savings and enhanced shopping experiences when there are multiple supermarkets to choose from (Widener et al., 2013; Battersby & Peyton, 2014).

In an MCDM process, the correlation between the number of supermarkets and district selection regarding supermarket accessibility may significantly impact how much weight is given to each consideration. It would be vital to consider the significance of variables about the number of supermarkets. In this context, the number of supermarkets in each district defines the supermarket quantity in the neighborhood. In this determination, the mobile phone application, which the Turkish Ministry of Health opened to the public free of charge in 2021, is used. In the application, named Hayat Eve Sığar (HES), the locations of supermarkets are shown on a map. With the help of the HES application, it is determined in which neighborhood the supermarkets are located with a meticulous study. Thus, the number of supermarkets in the neighborhoods is revealed to input this study.

Case Study

The study employs population metrics as a substitute for assessing traffic quantity (*EC1*), based on the foundation that larger urban populations often correspond to increased vehicular activities and heightened traffic volumes. Secondly, while the road network data for this experiment was obtained from a publicly available mapping software (*EC2*), a complete count of bus and tram stops within each district is carried out. (*EC3*). Lastly, the number of supermarkets in each district specifies the supermarket quantity in the area; thus, this data is gathered (*EC4*). In this way, Table 1 depicts a portion of the decision matrix. Our decision matrix is a 39 x 4 dimensional matrix (39 districts in Konyaaltı and 4 evaluation criteria) created by the decision maker once the options and assessment criteria are specified. The number of choice options along with evaluation criteria in our case are 39 and 4, respectively.

Table 1. A Sample of the Decision Matrix

District ID	*EC1*	*EC2*	*EC3*	*EC4*
M24	0.13	1	3	1
M25	3.17	8	13	2
M26	18.68	3	25	17
M27	10.55	9	25	11

Table 2 presents a representative portion of the decision or determination matrix's normalized form. The normalized or regulated decision matrix is calculated by computing the square root of the sum of squares of the values of each decision matrix criterion (sum of squares of the column values). Then, we divide the related component of the column by this value. If any member of the decision pattern has a value of 0, the corresponding element in the normalized decision matrix likewise has a value of 0.

Table 2. A Sample of the Normalized Decision Matrix

District ID	*EC1*	*EC2*	*EC3*	*EC4*

M27	0.20280	0.26820	0.29167	0.32325
M28	0.17152	0.20861	0.18667	0.14693
M29	0.28678	0.23841	0.31500	0.14693
M30	0.12978	0.14901	0.18667	0.17632

Table 3 demonstrates the main criteria weights acquired. At this stage, experts with relevant knowledge and expertise in the field assign weights to each criterion based on their subjective judgment. Experts use their experience and insights to detect the relative significance of four criteria in achieving the overall objectives of the decision-making process.

Table 3. Main Criteria Weights Obtained

District ID	***Criterion***	***Weight (%)***	***Rank***
EC1	Traffic Quantity	25	2
EC2	Road Network Density	25	2
EC3	Public Transportation Service	30	1
EC4	Supermarket Quantity	20	4

Results and Discussion

This section reveals the outcomes of the district ranking analysis within the Konyaaltı municipality of Antalya city, as presented in Table 4. The top-ranking districts, namely *M27*, *M33*, *M4*, *M3*, and *M26*, are identified, with *M27* securing the highest position according to the computed $P_{score,i}$. This ranking delineates a hierarchical order, designating *M33* and *M4* as second and third, respectively, while *M3* and *M26* claim the fourth and fifth positions.

Table 4. District Ranking in Konyaaltı Municipality of Antalya City

District ID	$P_{score,i}$	Rank	District ID	$P_{score,i}$	Rank	District ID	$P_{score,i}$	Rank
M27	0.67061	1	***M32***	0.51134	14	***M12***	0.47392	27
M33	0.60445	2	***M31***	0.50495	15	***M2***	0.47034	28
M4	0.58343	3	***M18***	0.49029	16	***M5***	0.46981	29
M3	0.57500	4	***M1***	0.48798	17	***M24***	0.46558	30
M26	0.57291	5	***M39***	0.48737	18	***M35***	0.46227	31
M30	0.54902	6	***M23***	0.48653	19	***M15***	0.46189	32
M7	0.54453	7	***M13***	0.48325	20	***M17***	0.46060	33
M25	0.53973	8	***M11***	0.48156	21	***M8***	0.45554	34
M21	0.53044	9	***M6***	0.48095	22	***M14***	0.45492	35
M29	0.52931	10	***M34***	0.48024	23	***M38***	0.45321	36
M28	0.52836	11	***M22***	0.47978	24	***M36***	0.45132	37
M9	0.52282	12	***M37***	0.47822	25	***M20***	0.45059	38
M19	0.51350	13	***M16***	0.47777	26	***M10***	0.44909	39

The success metrics associated with each district become apparent upon closer examination. District *M27*'s exemplary performance is ascribed to its strategic proximity to public transportation services (*EC3*), a high road network density (*EC2*), and a notable presence of supermarkets (*EC4*). Similarly, the commendable rankings of *M33*, *M4*, and *M3* are attributed to their robust road network density (*EC2*) and relatively favorable access to public transportation services (*EC3*). Furthermore, *M26* attains a respectable ranking courtesy of its advantageous proximity to public transportation services (*EC3*) and the abundance of supermarkets within its neighborhoods (*EC4*).

In contrast to the higher-performing districts, the analysis reveals a notable contrast in the performance metrics of certain districts within Konyaaltı municipality. District *M10* emerges as the district with the lowest $P_{score,i}$, indicative of its overall low-grade performance compared to its counterparts. Following suit, *M20* and *M36* secure the second and third positions as the second and third-worst performers, respectively. Additionally, *M38* and *M14* claim the fourth and fifth-worst positions, collectively comprising the districts with the most considerable room for improvement according to our evaluation criteria.

A notable observation is these districts' common and shared shortcomings, which are distinguished by unusually low ratings throughout the comprehensive evaluation criteria. While the absence of significant traffic quantity (*EC1*) could be perceived as advantageous in decision-making, these districts collectively need to improve in critical determinants. Specifically, each of these districts exhibits notably low road network density (*EC2*), limited or absent public transportation services (*EC3*), and a scarcity of supermarkets (*EC4*). This confluence of shortcomings highlights the intrinsic interdependence of multiple factors in influencing the overall performance of a district.

In addition, merely two districts in Konyaaltı municipality fall within the $P_{score,i}$ range of 0.6-0.7, signifying a noteworthy distinction from the remaining districts (Figure 1). Furthermore, while exactly one-third of the neighborhoods attained a $P_{score,i}$ within the range of 0.5-0.6, over half of them registered $P_{score,i}$ between 0.4 and 0.5. This outcome underscores the presence of substantial potential for improvement across numerous neighborhoods concerning transportation and supermarket accessibility, although there are high performance districts in Konyaaltı in Antalya.

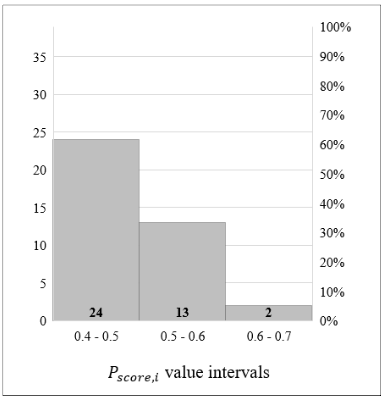

Figure 1. Distribution of $P_{score,i}$ values among the districts in Konyaaltı

Conclusion

This study, anchored in the evaluation of transportation attributes and supermarket accessibility within the districts of Konyaaltı municipality, yields insightful findings that hold implications for urban transportation, planning, and development. As elucidated in the introduction, the escalating urbanization and the related need for efficient transportation systems underscore the necessity for a robust MCDM framework. In this manner, utilizing the TOPSIS allows for an assessment of the 39 districts, identifying both high-performing and underperforming districts based on $P_{score,i}$ values.

The top-ranking districts, obviously presenting *M27* as the leader, emerge as archetypes of the successful context of transportation and supermarket accessibility. District *M27*, securing the highest position, demonstrates a fully developed performance attributed to its proximity to public transportation services (*EC3*), high road network density (*EC2*), and a significant presence of supermarkets (*EC4*). Similarly, districts *M33*, *M4*, *M3*, and *M26* exhibit worthy rankings, displaying strengths in road network density (*EC2*) and access to public transportation services (*EC3*).

On the contrary, a subset of districts, particularly *M10, M20, M36, M38,* and *M14,* appear as regions with considerable room for improvement. These districts, as revealed by their remarkably low $P_{score,i}$, present a shared challenge characterized by deficiencies in road network density (*EC2*), limited or absent public transportation services (*EC3*), and a scarcity of supermarkets (a low level of *EC4*). Despite their low traffic quantity (*EC1*) advantage, these districts highlight the interdependence of multiple factors in influencing overall district performance. Additionally, the results highlight significant potential for improvement in numerous districts, despite the presence of high-performance districts in Konyaaltı, Antalya.

The observed shortcomings provide a foundation for transportation authorities and policymakers to strategically focus on interventions to improve transportation infrastructure and accessibility to important facilities such as supermarkets in urban areas. The confluence of low scores across evaluation criteria suggests an opportunity for integrated and comprehensive transportation systems development initiatives. Strategies could include enhancing road network density, introducing or improving public transportation services, and strategically allocating amenities such as supermarkets to address accessibility gaps.

In conclusion, the findings presented herein contribute to the broader discourse on sustainable urban transportation systems development by emphasizing the integral relationship between transportation attributes and the accessibility of key facilities. The systematic evaluation assisted by the TOPSIS technique provides a valuable tool for decision-makers to prioritize and optimize interventions. Future research may look deeper into underperforming districts' specific challenges and further explore targeted solutions to improve the overall transportation systems and infrastructure.

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CHAPTER III

Frame System Analysis with Stochastic Finite Element Method

Özlem ÇAVDAR[1]

Introduction

The fact that our country is located in an active earthquake zone and the loss of life and property as a result of earthquakes is an indication that there are some deficiencies in the project design or implementation stages of building systems. One of these shortcomings is that the structure parameters used during the analysis are considered deterministic. Deterministic methods are based on complete knowledge of these parameters. However, there is some uncertainty about knowing the design values with certainty. Examples of these uncertainties are the geometric properties of building elements, the mechanical properties of materials, and the size and distribution of loads (Lawrence, 1987). Due to these

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uncertainties, the deterministic approach may be insufficient in the analysis of many building systems. Probabilistic analysis methods are mostly applied in simple or semi-complex building systems in various fields of civil engineering and are increasing their reliability day by day. Different analytical methods have been developed for the analysis of structures with stochastic (indeterminate) material and geometry properties. However, the calculation of these methods either takes a long time or can only be applied to certain types of structures. Researchers who developed the finite element method, a numerical approach to solving structural problems with arbitrary material properties, call this method the stochastic finite element method (SFEM) (Augusti & et al., 1984 and Liu & et al., 1987). The second important method developed in this field is the Monte Carlo simulation (MCS) method.

The accuracy of the calculation methods used in the analysis of building systems is taken one step further by taking into account the uncertainties in the buildings. In this direction, the main purpose of this study is to examine the current application areas of SFEM analysis for the analysis of carrier systems with stochastic geometry and material properties and to develop new methods for some application areas that are not yet frequently encountered in the literature.

As a result of the researches, it has been determined that the two most common methods developed for probabilistic analysis of structures, taking into account the uncertainty situations, are SFEM and MCS methods. The SFEM method was formulated in its simplest form by Kleiber & Hien, 1992. In order to demonstrate the dynamic analysis applications of SFEM, this method was applied to simple and semi-complex frame systems in two and three dimensions under earthquake load, and as a result of the analysis, displacement and cross-sectional effect values were obtained in case of random variables of material and geometric properties, and the results were compared with the results obtained from the MCS method.

Stochastic Finite Element Method (SFEM)

This method is considered one of the most widely used stochastic finite element methods for analyzing indeterminate systems. SFEM is created by extending all the random variables of an indeterminate system around their mean values with the help of Taylor series and consists of deriving the analytic expression for the change of the desired response qualities of a structure, such as mode shapes and natural frequencies, due to the small variation of random variables. Since 1960, the method has been an effective method used to solve stochastic finite element problems. Boyce & Goodwin (1964) were among the first to use the stochastic method to solve the eigenvalue problem of random beams and springs.

The deterministic equation of motion of a system with n degrees of freedom is,

$$\boldsymbol{M_{\alpha\beta}\ddot{q}_{\beta} + C_{\alpha\beta}\dot{q}_{\beta} + K_{\alpha\beta}q_{\beta} = Q_{\alpha}} \quad (1)$$

can be written as. Here it shows the stiffness, mass, and damping matrices of the system, the total acceleration, velocity, and displacement vectors, and the external load vector, respectively. The SFEM approach consists of starting from deterministic equations and tracing the resulting equations to the second degree. $K_{\alpha\beta}, M_{\alpha\beta}, C_{\alpha\beta}\ddot{q}_{\beta}, \dot{q}_{\beta}, q_{\beta}Q_{\alpha}$

Perturbation-based stochastic finite element equations describing the dynamic behavior of a system with one random variable (Kleiber & Hien 1992):

Zero degrees (linear simultaneous system of ordinary difference equations for terms N, ϵ^0 $q_{\alpha}^{0}(b_l^0;\tau), \alpha = 1,2,\ldots,N$)

$$\boldsymbol{M_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + C_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + K_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) = Q_{\alpha}^{0}(b_l^0;\tau)} \quad (2)$$

First-order (linear concurrent systems of ordinary difference equations for terms N,Є[1] $q_{\alpha}^{\prime\rho}(b_l^0;\tau), \rho = 1,2,\ldots,N^-, \alpha = 1,2,\ldots,N)N^-$

$$\boldsymbol{M_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau) + C_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau) + K_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau)}$$
$$= \boldsymbol{Q_{\alpha}^{\prime\rho}(b_l^0;\tau)}$$
$$-\left[\boldsymbol{M_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + C_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + K_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{0}(b_l^0;\tau)}\right] \quad (3)$$

The quadratic (N is a system of linear simultaneous equations of ordinary differences, $Є^2 q_{\alpha}^{2}(b_l^0;\tau), \alpha = 1,2,\ldots,N)$

$$M_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau) + C_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau) + K_{\alpha\beta}^{0}(b_l^0)q_{\beta}^{\prime\rho}(b_l^0;\tau)$$
$$= \{Q_{\alpha}^{\prime\rho\sigma}(b_l^0;\tau)$$
$$-2\left[M_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{\prime\sigma}(b_l^0;\tau) + C_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{\prime\sigma}(b_l^0;\tau) + K_{\alpha\beta}^{\prime\rho}(b_l^0)q_{\beta}^{\prime\sigma}(b_l^0;\tau)\right]$$
$$-\left[M_{\alpha\beta}^{\prime\rho\sigma}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + C_{\alpha\beta}^{\prime\rho\sigma}(b_l^0)q_{\beta}^{0}(b_l^0;\tau) + K_{\alpha\beta}^{\prime\rho\sigma}(b_l^0)q_{\beta}^{0}(b_l^0;\tau)\right]\}S_b^{\rho\sigma} \quad (4)$$

$$q_{\alpha}^{(2)}(b_{\ell}^0;\tau) = q_{\alpha}^{\prime\rho\sigma}(b_{\ell}^0;\tau)S_b^{\rho\sigma} \quad (5)$$

In these formulations $b_{\ell}^0 M_{\alpha\beta}^0, C_{\alpha\beta}^0 K_{\alpha\beta}^0, Q_{\alpha}^0, q_{\beta}^0$ and $S_b^{\rho\sigma}$ nodal point random variables, system mass matrix, damping matrix, system stiffness matrix, charge vector, displacement, and node random variables vector express covariance matrix, respectively. N^- is the number of random variables, and N is the number of degrees of freedom in the system.

In equations (6-9), the first and second derivatives of zero-order mass, damping, stiffness matrices, and charge vectors with respect to the nodal point random variable are defined as follows: b_{ℓ}

Zero-order functions;

$$M_{\alpha\beta}^{0}(b_{\ell}^0) = \int_{\Omega} \phi_{\bar{\alpha}} \ell_{\bar{\alpha}}^0 \phi_{i\alpha}\, \phi_{i\beta}\, d\Omega \quad (6)$$

$$C^{0}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, \phi_{\bar{\beta}} (\phi^{0}_{\bar{\alpha}} \ell^{0}_{\bar{\beta}} \phi_{i\alpha} \phi_{i\beta} + \beta^{0}_{\bar{\alpha}} C^{0}_{ijkl\bar{\beta}} B_{ij\alpha} B_{kl\beta}) d\Omega \qquad (7)$$

$$K^{0}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, C^{0}_{ijkl\bar{\alpha}} B_{ij\alpha} B_{kl\beta}\, d\Omega \qquad (8)$$

$$Q^{0}_{\alpha}(b^{0}_{\ell};\tau) = \int_{\Omega} \phi_{\bar{\alpha}} \phi_{\bar{\beta}} \ell^{0}_{\bar{\alpha}}\, f^{0}_{i\bar{\beta}} \phi_{i\alpha}\, d\Omega + \int_{\partial\Omega\sigma} \phi_{\bar{\alpha}}\, \hat{t}^{0}_{i\bar{\alpha}} \phi_{i\alpha}\, d(\partial\Omega) \qquad (9)$$

First partial derivatives;

$$M^{,\rho}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, \ell^{,\rho}_{\bar{\alpha}} \phi_{i\alpha} \phi_{i\beta}\, d\Omega \qquad (10)$$

$$C^{,\rho}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, \phi_{\bar{\beta}} [(\alpha^{,\rho}_{\bar{\alpha}} \ell^{0}_{\bar{\beta}} + \alpha^{0}_{\bar{\alpha}} \ell^{,\rho}_{\bar{\beta}}) \phi_{i\alpha} \phi_{i\beta}$$

$$+(\beta^{,\rho}_{\bar{\alpha}} C^{0}_{ijkl\bar{\beta}} + \beta^{0}_{\bar{\alpha}} C^{,\rho}_{ijkl\bar{\beta}}) B_{ij\alpha} B_{kl\beta}] d\Omega \qquad (11)$$

$$K^{,\rho}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, C^{,\rho}_{ijkl\bar{\alpha}} B_{ij\alpha} B_{kl\beta}\, d\Omega \qquad (12)$$

$$Q^{,\rho}_{\alpha}(b^{0}_{\ell};\tau) = \int_{\Omega} \phi_{\bar{\alpha}} \phi_{\bar{\beta}} (\ell^{,\rho}_{\bar{\alpha}}\, f^{0}_{i\bar{\beta}} + \ell^{0}_{\bar{\alpha}} f^{,\rho}_{i\bar{\beta}}) \phi_{i\alpha}\, d\Omega +$$
$$\int_{\partial\Omega\sigma} \phi_{\bar{\alpha}}\, \hat{t}^{,\rho}_{i\bar{\alpha}} \phi_{i\alpha}\, d(\partial\Omega) \qquad (13)$$

Second partial derivatives;

$$M^{,\rho\sigma}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, \ell^{,\rho\sigma}_{\bar{\alpha}} \phi_{i\alpha} \phi_{i\beta}\, d\Omega \qquad (14)$$

$$C^{,\rho\sigma}_{\alpha\beta}(b^{0}_{\ell}) = \int_{\Omega} \phi_{\bar{\alpha}}\, \phi_{\bar{\beta}} [(\alpha^{,\rho\sigma}_{\bar{\alpha}} \ell^{0}_{\bar{\beta}} + \alpha^{,\rho}_{\bar{\alpha}} \ell^{,\sigma}_{\bar{\beta}} + \alpha^{,\sigma}_{\bar{\alpha}} \ell^{,\rho}_{\bar{\beta}} + \alpha^{0}_{\bar{\alpha}} \ell^{,\rho\sigma}_{\bar{\beta}}) \phi_{i\alpha} \phi_{i\beta}$$

$$+(\beta^{,\rho\sigma}_{\bar{\alpha}} C^{0}_{ijkl\bar{\beta}} + \beta^{,\rho}_{\bar{\alpha}} C^{,\sigma}_{ijkl\bar{\beta}} + \beta^{,\sigma}_{\bar{\alpha}} C^{,\rho}_{ijkl\bar{\beta}} + \beta^{0}_{\bar{\alpha}} C^{,\rho\sigma}_{ijkl\bar{\beta}}) B_{ij\alpha} B_{kl\beta}] d\Omega \qquad (15)$$

$$K_{\alpha\beta}^{,\rho\sigma}(b_\ell^0) = \int_\Omega \phi_{\bar{\alpha}}\, C_{ijkl\bar{\alpha}}^{,\rho\sigma} B_{ij\alpha} B_{kl\beta} d\Omega \tag{16}$$

$$Q_\alpha^{,\rho\sigma}(b_\ell^0;\tau) = \int_\Omega \phi_{\bar{\alpha}}\phi_{\bar{\beta}}(\ell_{\bar{\alpha}}^{,\rho\sigma}\, f_{i\bar{\beta}}^0 + \ell_{\bar{\alpha}}^{,\rho} f_{i\bar{\beta}}^{,\sigma} + \ell_{\bar{\alpha}}^{,\sigma} f_{i\bar{\beta}}^{,\rho} + \ell_{\bar{\alpha}}^0 f_{i\bar{\beta}}^{,\rho\sigma})\phi_{i\alpha} d\Omega + \int_{\partial\Omega\sigma} \phi_{\bar{\alpha}}\, \hat{t}_{i\bar{\alpha}}^{,\rho\sigma} \phi_{i\alpha} d(\partial\Omega) \tag{17}$$

All functions in equations (10-17) are evaluated in the mean of the nodal point random variable (b_ℓ) and (b_ℓ^0). There Ω and $\partial\Omega$ and the finite element spacing and three-dimensional boundary, $\phi_{i\alpha}$, $\phi_{\bar{\alpha}}$ denote the system shape function matrix and the shape-change function for the $\bar{\alpha}$'th node. $B_{ij\alpha}$ the deformation node displacement matrix, ℓ the correlation coefficient, $C_{ijkl\bar{\alpha}}$ shows the fundamental tensor for the $\bar{\alpha}$' th node. f_i and $\hat{t}_i$ is the vector of body forces and the boundary drawing vector. $(.)^0$, $(.)^{,\rho}$ ve $(.)^{,\rho\sigma}$ zero degree quantities that take the averages of random variable express first partial derivatives with respect to nodal point random variables and second partial derivatives with respect to nodal point random variables.

SFEM analysis requires knowing only the first two moments of random variables. The purpose of this method is to calculate the first and second moments (mean and variance) of the response quantities. Statistical techniques such as MCS, on the other hand, require knowledge of probabilistic density functions, which do not exist in practice. The stochastic finite element method considers a system of zeroth-degree equations, first-degree equations, and second-degree equations for each of the random variables, as seen in equations (6) to (9). The number of linear system solutions required is equal to twice the number of node random variables. Moreover, this method does not restrict the analysis of some boundaries of random fields, as is the case with statistical methods. SFEM can be applied to both homogeneous and inhomogeneous random fields without requiring a normal approach (Zhang & et al., 1996;

Chaudhuri & Chakraborty, 2005). This non-statistical technique works very effectively when the fluctuations of random field variables are small and the coefficient of variation (COV) is quite good, up to 0.15 (Kleiber & Hien, 1992; Bhattaccharyya & Chakraborty, 2002; Çavdar & et al., 2011; Çavdar & et al., 2015).

The mass, damping, stiffness matrices, and charge vectors ($M^0_{\alpha\beta}, C^0_{\alpha\beta}, K^0_{\alpha\beta}, Q^0_{\alpha}$) on the left side of equations (6)-(9) are related to the deterministic system and can be determined by the conventional finite element method. The first and second partial derivatives of $M_{\alpha\beta}, C_{\alpha\beta}$, $K_{\alpha\beta}$ and Q_{α} with respect to the nodal point random variables, these matrices and vectors can be calculated precisely if they are explained in a close form with respect to the nodal point random variable.

After the random field variables were explained according to the nodal point values, the equations of the general mass, damping, stiffness matrices and load vectors of the structural system were created and the first and second partial derivatives were evaluated according to the nodal point random variable. The operation steps of equations (6)-(9) are as follows:

a) In equation (6), the generalized nodal point accelerations($\ddot{q}^0_{\alpha}$) velocities ($\dot{q}^0_{\alpha}$) and displacements (q^0_{α}) are solved for the zeroth degree.

b) The first-order charge vector on the right side of equation (7) is created and the first-order equations are solved for $\ddot{q}^{,\rho}_{\alpha}$,$\dot{q}^{,\rho}_{\alpha}$ ve $q^{,\rho}_{\alpha}$.

c) The second-order load vector on the right side of equation (8) is generated, and the quadratic equation is solved for $\ddot{q}^2_{\alpha}$, $\dot{q}^2_{\alpha}$ ve q^2_{α}.

d) Expected values and covariances for expression variables are evaluated.

For random fields, the first two statistical moments can be determined as follows:$b_r(x_k), r = 1,2,\ldots,R,$

$$E[b_r] = b_r^0 = \int_{-\infty}^{+\infty} b_r\, p_1(b_r) db_r \quad (18)$$

$$Cov(b_r, b_s) = S_b^{rs} = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} (b_r - b_r^0)(b_s - b_s^0) p_2(b_r, b_s) db_r db_s \quad (19)$$

$r, s = 1,2, \dots, R$ for

$$S_b^{rs} = \alpha_{b_r} \alpha_{b_s} b_r^0 b_s^0 \mu_{b_r b_s} \quad (20)$$

$$\alpha_{b_r} = \left[\frac{Var(b_r)}{b_r^0}\right]^{1/2} \mu_{b_r b_s} = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} b_r b_s\, p_2(b_r, b_s) db_r db_s \quad (21)$$

It is expressed in the form of. Here; The expected value is indicated by the covariance of Cov (br, bs) and the variance of Var (br), $E[b_r]$ which is the correlation function, the coefficient of variation, and the probability density function (PDF). Probability is the node of the density function. R is the random variable (modulus of elasticity refers to randomness such as mass density, cross-sectional area, etc.). If all the equations here are solved for zeroth, first, and second degree displacements, velocities, and accelerations; The first two moments of probability are calculated.

Monte Carlo Simulation (MCS) Method Formulation

Probabilistic methods are commonly used to deal with stochastic problems and can be grouped into statistical and non-statistical approaches. As discussed in the previous section, the perturbation method does not take into account the true probabilistic distribution of random parameters using the variation of random parameters from the mean values of random variables. A numerical simulation program was needed to calculate the true random behavior of the input parameters. The most widely used numerical simulation technique is the MCS method. The MCS method is a specialized technique used to produce results numerically without performing any physical testing (Melchers, 1999). In this technique, the values of indeterminate parameters are randomly selected to calculate the probabilities of the problem that will arise. These values are selected according to the probability distribution and taken from a fixed field. In the MCS method, the random selection process is often repeated to best obtain the correct result. In each repetition, a random value is selected and produces a possible solution. Thus, the solution of the problem is obtained (Melchers & Ahammed, 2004).

This method can address both time-dependent and time-independent uncertainty problems. Randomness numbers that represent problem variables are generated by a computer program. By decomposing the covariance matrix, randomly related variables can be generated. Although the versatility of the MCS method is an important feature, the method takes too long from the point of view of the CPU (processor) to achieve statistical convergences. Therefore, this realistic method is most often used to check the validity of other approximate methods.

The MCS method is a very useful mathematical tool that deals with situations that all other methods cannot solve. Shinozuka (1972) was one of the first to use this method to solve structural dynamics problems. He used this approach to simulate earthquake recordings, the height of sea waves, and other random events. Zhang & Chen (1991) and Zhang & Ellingwood (1996) also used this method to derive the effects of random material properties. In most of the studies, the MCS method was used to confirm the results obtained from approximate methods. In this study, the MCS method will be used to confirm the results obtained from perturbation-based SFEM.

This method works with a set of random values generated according to the probability density function of the random variable X. The random values selected for the variable are: X={x1, x2, x3, ... xN}. where N denotes the number of simulations. In this method, stiffness and mass matrices are created for each X value and the desired values (e.g. displacement and stress values) are calculated. At the end of the N simulations, displacement and stress vectors are obtained for each random value of the variable. expected displacement and stress values (average values) to show displacement vectors, stress vectors;

$$E_{\{q_\beta\}} = \frac{1}{N}\sum_{i=1}^{N}\{q_\beta\}_i \tag{22}$$

$$E_{\{\sigma\}} = \frac{1}{N}\sum_{i=1}^{N}\{\sigma\}_i \tag{23}$$

It is formed in the form of.

Three-Dimensional Frame Analysis

Using the three-dimensional frame system model, the results obtained from the Structural Analysis Program 2000 (SAP 2000) (Wilson, 1997) program and the stochastic dynamic analysis results were compared with the results obtained from the MCS method and the deterministic analysis results were checked. For this purpose, a three-dimensional frame system with 10 floors, 3 spans, 3 spans in the X direction and 2 openings in the Y direction was selected as the sample model (Figure 1). For this frame system model, each span is 4 m in the x direction, 3 m in the y direction and the floor heights are 3 m. Random dynamic analyses for the coefficient of change (COV) of 15% were performed assuming that the modulus of elasticity for the framework system model changes randomly.

In the selected frame model, the cross-sectional dimensions of the column and beam elements were selected as 900 mm × 450 mm, 700 mm × 400 mm, respectively. In the frames used in the study, it was taken into account that the larger of the column cross-sectional dimensions was in the direction of bending. As proposed in TS 500 (2000), the modulus of elasticity (E) of the material is 2.8×107 kN/m2 and the unit weight and poisson's ratio (ν) of the concrete are taken as 25 kN/m3 and 0.2, respectively. During the calculations, the masses of the columns were determined depending on the cross-sectional dimensions, but the masses of the beams were calculated using the mass approach added in addition to the cross-sectional dimensions with the assumption that the beams received a load of 20 kN/m from the floors and walls.

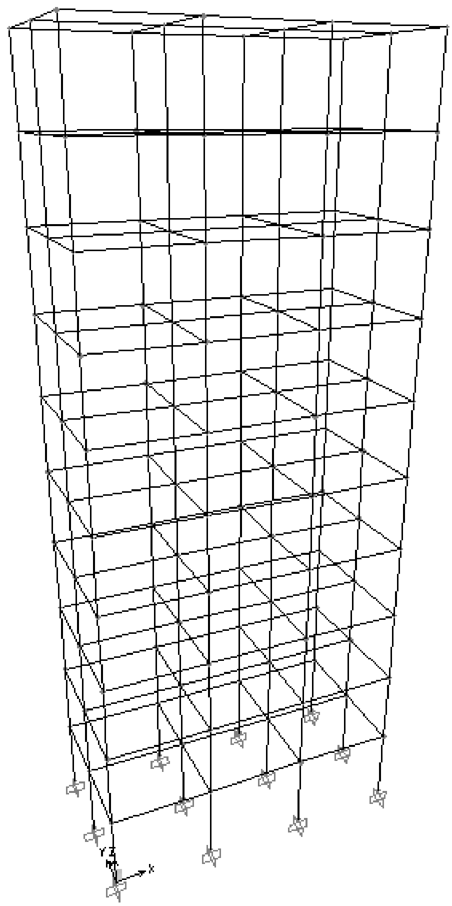

Figure 1. 10 times, 3 in the X direction, 2 in the Y direction span, three-dimensional frame model

In the analysis, the YPT330 component acceleration record of the 17 August 1999 Kocaeli earthquake was used (URL-1, 2010). It has been accepted that earthquake acceleration affects the horizontal direction in the examined building type systems and in the vertical direction in bridge type systems. The maximum acceleration of the Kocaeli earthquake is 0.349g and the acceleration record of the earthquake is given in Figure 2.

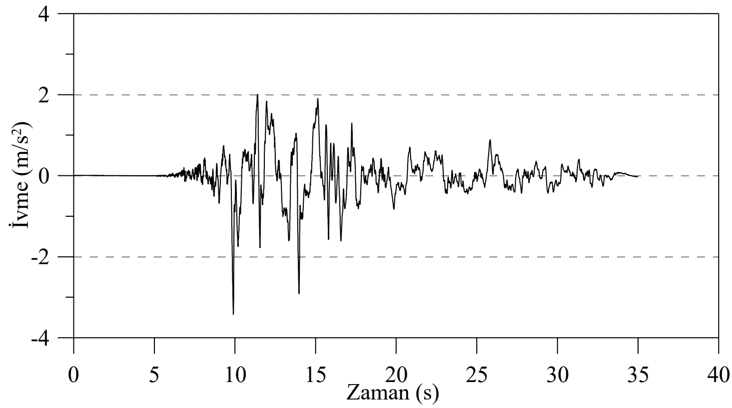

Figure 2: Acceleration record of the YPT330 component of the 1999 Kocaeli earthquake.

Frequencies and Displacements

As can be seen from Table 1, for the elasticity modulus selected as a random variable, the frequency values obtained as a result of the deterministic solution of the SFEM program of the framework system and the frequency values obtained from the SAP 2000 package program are approximately equal. When the results of stochastic dynamic analysis performed separately according to SFEM and MCS methods are examined, it is seen that the results of the two methods almost overlap. With this similar situation, the correctness of the results is confirmed.

Table 1. *Natural frequency values for the random variable modulus of elasticity of the three-dimensional frame system model*

Mode number	Frequencies (Hz)		
	Deterministic	Stochastic	
	SAP 2000	SFEM	MCS
1	1.020	1.056	1.110
2	1.360	1.425	1.360
3	1.369	1.437	1.425
4	3.187	3.311	3.278
5	4.043	4.221	4.200

The selected earthquake acceleration record (Figure 2) was applied to the frame system in the X direction and the dynamic responses of the frame system were obtained at a time interval of 0.005 s. Accordingly, the displacements obtained from the SFEM method generally follow a course close to the displacement values obtained from the MCS methods along the floor level. If expressed in numerical data, the horizontal displacement values obtained from the 10-storey frame by the SFEM method differ by approximately 9.80% on the first floor compared to the MCS method, while this difference decreases rapidly towards the upper floors and decreases to 3.3% on the top floor. In other words, while the horizontal displacement value obtained from the SFEM method for the top floor is approximately 9 cm, this value is 9.34 cm in the MCS method. As a result of the deterministic analysis, this value was obtained as 10.5 cm.

Conclusions

Taking into account the uncertainty situations, it has been determined that the two most common methods developed for the probabilistic analysis of structures are SFEM and MCS methods. Therefore, assuming that material and geometric properties are variable, stochastic dynamic analysis of a building system was carried out according to two methods, and then the results of both methods were compared with each other.

In order to demonstrate the dynamic analysis applications of SFEM, this method was applied to three-dimensional frame systems under earthquake load, and as a result of the analysis, frequencies, displacement and cross-sectional effect values were obtained in case of random material and geometric properties, and the results were compared with the results obtained from the MCS method. Random change of material properties (modulus of elasticity and bulk density), geometric properties (cross-sectional area) were taken into account. As a result of non-deterministic dynamic analysis, it was obtained that both methods gave similar results. It is important to perform uncertainty analysis of building systems under uncertain dynamic loads such as earthquakes.

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CHAPTER IV

Consultancy and Owner Representation Service in Construction Management

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Introduction

In a typical construction work, there are generally two parties: the owner of the work and the contractor who undertakes the construction of the work (Contractor). At first glance, it is thought that all the work to be done during the construction process is carried out by the contractor. However, there are quite extensive works and procedures that need to be done by the owner, and the expected quality of the resulting product is directly related to the proper performance of these works. For example, in the preparation phase for construction, in addition to the preparation of projects and

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specifications, preparation of the contract draft and management of the tender process, the owner is expected to effectively supervise the work during the implementation phase. All of the works in question are technical and require expert knowledge. Therefore, it is undoubted that not every owner can carry out these transactions to the required extent with his/her own knowledge and experience. As a result, construction works often do not meet the owner's expectations in terms of planned quality, time and cost, and disputes between the parties are inevitable. The size and complexity of the projects increase the scope of the problems in question and cause significant losses to the parties (Öcal, 2015).

In building production, in order to meet the owner's expectations and prevent possible grievances, as well as to minimize the problems caused by the owner, the most effective method is to get professional support from experts or organizations to assist the owner in the work he needs to do. This support that the owner will receive is called 'consultancy' or 'owner representation' depending on its content (Haltenhoff, 1999). Since the person or organization who will serve as a consultant or owner representative will perform an interdisciplinary function due to their duties, those who will undertake this task require knowledge and equipment in many areas that will be grouped under the heading of "management", in addition to classical engineering and architecture knowledge. For the reasons stated, in any construction work where modern construction management is valid; Unlike engineering-architecture services that involve the owner, contractor, design and construction phase, a service approach that requires interdisciplinary professionalism and teamwork has developed under the name of consultancy and owner representation (COR). This service approach takes place as a fourth party within the scope of project management to carry out the necessary work on behalf of the owner throughout the building life cycle and to meet its information and guidance needs (Foster, 1983; Conner,1983; Haltenhoff, 1999, Shohet and Frydman, 2003; McKEON, 2012; Diao, Dong & Cui, 2018; Demetracopoulou, O’brien & Khwaja, 2020; Zhong & et al., 2023; Taheriboshrouyeh, Malindu & Sam, 2023).

Depending on the scope of the project and the scope of the owner's own financial resources, the scope of external professional support varies and the service received accordingly is called "Consultancy", "Owner Representation" or "Construction Management". The content and scope of the service to be received is determined by the contract between the owner and the service provider. Although the development of consultancy and owner representative services in the building production process has been developed and implemented long ago, the outlined project management options are currently being implemented except for a small number of detailed projects. Within the scope of this study, the concept and definition of the Consultancy and Owner Representative service in the construction sector, its development process and today's application conditions at home and abroad have been examined and suggestions have been presented.

Consultancy and Owner Representative Service

Consultant, in its simplest form, is defined in the dictionary of the Turkish Language Association as "an official who is consulted to obtain information and opinions, consultant"; Consultancy is defined in the same glossary as "the task performed by the consultant, consultancy". Depending on the field of interest and expertise of the consultancy is also called as consultancies may include legal consultancy, technical consultancy, financial consultancy/consultancy, etc.

Regardless of the field or subject, the product option offered provides the information and/or suggestions requested, but is subject to evaluation and evaluation by discussing the extent to which it will be used. Addressing the subject specifically production management operations; “Owner Representative” and “Construction Manager”, unlike consultancy, are assigned with the authority to take initiative on behalf of the owner and assume responsibilities. However, sometimes, depending on the content of the contract between the parties, some options of the same service provider are made, and some people assume the duty and authority of owner representative and/or construction manager. For this reason, there may be some nuances in these three work descriptions within the scope of construction works. This skill is covered variously in the literature on consulting, owner representation and construction management, as summarized below. For example, in the book titled Contract Management in Construction Projects (Öcal, 2015); The consultant, owner manager and construction manager who undertake duties on behalf of the owner are called "Professional Service Provider" and one of them will be as follows:

"The Consultant monitors the process of the realization of the Project, carries out the necessary organizational work to ensure that there are no deficiencies or disruptions in the performance of the powers and responsibilities of the parties and those working on their behalf in the context of the contract, manages the reporting circulation that develops within the scope of these studies, and identifies potential conditions and events that may cause problems between the parties. Person or organization that develops precautions and presents them to the parties; Owner Representative, an expert and experienced person or organization who is contractually authorized to act on behalf of the Owner in certain matters; "Construction Manager is the person or organization who assumes comprehensive responsibility towards the owner within the scope of making and implementing all kinds of decisions regarding the planning, coordination, realization and supervision of all activities for the completion of the construction in accordance with the contract and its annexes."

The term "Consultant" or "Technical consultant" is defined by the Turkish Association of Consulting Engineers and Architects (TürkMMMB, 2012) as follows (TürkMMMB, 2014b):

"Consulting engineer and architectural service; Having experience in one or more branches of engineering and architecture, having sufficient theoretical and practical knowledge and providing intellectual services based on technology, knowledge and thought on the natural or built environment, working in areas covering Technical Consultancy work subjects, independent consultancy engineering and architecture profession both nationally and internationally. "It is a person or organization that assumes responsibility towards the owner to provide independent consultancy engineering and architecture in accordance with the internationally recognized rules of professional ethics."

According to the Public Procurement Law No. 4734; In the tenders to be made by public institutions and organizations that are subject to public law or under public control or using public resources, the definition of "consultant" under the heading of definitions in Article 4 is made as follows:

“Consultant: It refers to the service providers who provide consultancy services, who use their knowledge and experience for the benefit of the administration, who do not have any organic ties with the contractors of the work they advise, who do not gain any income from the administration other than the consultancy service fee, and who provide consultancy services.”

Consultancy and consultancy services are provided by the American Institute of Architects (AIA), the Associated General Contractors of America (AGC) and the Construction Management Association of America (CMAA), which are professional organizations that have gained a well-established institutional qualification in the United States of America. Individuals or organizations that provide owner representation services are called "construction managers". However, depending on its content, the service offered is detailed as consultancy, owner representation or construction manager. In this context, the Construction Manager;

AIA, Architect who provides COR services to the owner and acts on behalf of the owner for the benefit of the owner in all situations encountered during this service (Mutchler & Widener, 2000);

AGC is a person or organization that works to provide COR services to the Owner at various stages of the project and forms the project team in a way that increases the benefit of the owner;

CMAA defines it as "a person or organization that provides COR services to the Owner with its expertise and resources."

Considering the evaluations summarized above, in this study, it is accepted that the concepts of consultant, owner representative and construction manager include the issues in the following definitions:

Consultant: An expert and experienced person or organization who is consulted at all or some stages of the work and transactions from the beginning to the completion of the project in building production;

Owner Representative: An expert and experienced person or organization who is contractually authorized to act on behalf of the owner in certain matters;

Construction Manager: The person or organization authorized by the owner to make all kinds of decisions regarding the planning, coordination, realization and supervision of all activities for the completion of the construction in accordance with the contract and its annexes.

Since construction management has the characteristics of an owner representative' with expanded powers and responsibilities in terms of its obligations towards the owner and the scope of the service provided, the term "Consultant and owner Representative" will be used in this study to represent all three service providers.

COR service in domestic

Currently, professional COR are available at a very limited level and only in large projects. It can be said that construction management does not exist at all if the definitions in the literature and contemporary practices are not taken into account. In public and private performance level, the situations and frequency of usings of COR services are summarized under separate headings below.

COR service in public affairs

In our country, public construction investments are mostly made in accordance with the principles set out in the Public Procurement Law No. 4734; Special works that are not subject to this law are carried out by subject-specific tender method. In the article of the public procurement law that regulates consultancy services, "Technical services such as architecture and engineering, survey and project, map and cadastre, zoning plans of all sizes, zoning application, report preparation, plan, software development, design, technical specification preparation, audit and controllership, etc. Services in financial, legal or similar fields are received from consultancy service providers." It is said. With this definition, the services received within the scope of this law are "service procurement" rather than consultancy or owner representation. In other words, the works carried out within the scope of the relevant regulation are a service procurement that aims to have the works in question done by the private sector by tendering in cases where the public does not have the necessary number and quality of human resources to do these works. In large and special construction works that are not subject to the tender law, the public receives consultancy and/or owner representation services in different contexts. These services are mostly aimed at preparing feasibility studies, commissioning projects and fulfilling the contract management function during the construction implementation process. Preparation of feasibility studies and preliminary projects is in the nature of consultancy or owner representation, depending on the expectations of the owner. However, since the task of monitoring the process during the implementation phase of the project and supervising its implementation in accordance with the contract conditions is transferred to companies specialized in contract management, the format of this service procurement is suitable for owner representation.

Mass Housing Administration (TOKİ), whose duties, powers and procedures are regulated by Law No. 2985 and is mainly engaged in housing production in our country, is also a public institution that widely receives COR services. This services, which can be grouped in three groups as "Management Consultancy", "Project and Technical Services Consultancy" and "Construction Supervision Services Consultancy", from consultancy firms or private consultancy firms in which it is a shareholder (T.C. Sayıştaş Başkanlığı, 2013).

COR service in private sector

While privately owned constructions belonging to real and legal persons were inspected by Technical Implementation Officer (TIO) whom is technical staff authorized within the scope of Article 58 of Law No. 3194 until 2001, with the Construction Inspection Law No. 4708 published in 2001, firstly in 19 pilot provinces. And since 2011, it has started to be inspected by building inspection companies in all provinces. According to the relevant law, buildings with a maximum of two floors excluding the basement and a total construction area of 200 m^2 and smaller can still be inspected by TIO. Although the effectiveness of inspection has partially increased with building inspection companies, there is not much difference between building inspection companies and TIO in terms of their relations with the building owner, their duties and operations. The purpose of both systems is to inspect, on behalf of the public, the construction of real and legal persons in accordance with their licenses and annexes. In both control systems, after the projects are prepared by the building owner, they assume responsibility towards the licensing authority and the building owner to ensure that the construction process is carried out in accordance with the license and its annexes.

In the current situation, although building inspection companies and technical personnel who can assume TIO authority in small constructions act as a kind of employer representative during the drilling process on behalf of the employer, they seem to be essentially responsible to the licensed authority and their activities are carried out by working with the licensing authority. For this reason, the current practice does not comply with the general policies of the employer's representation, since the powers to be delegated by the employer and the mutual duties and responsibilities are not divided by the contract they will prepare with their free will. Especially in the construction of ordinary buildings, the employer does not receive consultancy and/or construction representation services within the scope of the definition in the literature in terms of preparation, determination of the appropriate contractor and inspection company, production process duration and inspection from the quality perspective.

In addition, in our country, corporate qualified employers generally receive consultancy services in the feasibility, design and preliminary project stages of special construction works, and employer representation services for contract management in the implementation phase. Therefore, consultancy firms have been established in our country to provide these services, albeit at a very limited level. In this case, an organization was formed under the name of Turkish Consulting Engineers and Architects Association (TürkMMMB) in order to gather consultancy companies within itself. Founded on April 25, 1980, TürkMMMB became a member of the International Federation of Consulting Engineers (FIDIC) in 1987, with the aim of reaching a certain standard in the field of consultancy services, which has been institutionalized in developed countries, and is the only representative of the institution in Turkey. It also became a full member of the European Federation of Engineering Consultancy Associations (EFCA) in 2001. Thus, TürkMMMB; It paved the way for the formation of independent consultancy engineering companies in accordance with FIDIC standards. Currently, the institution has 97 full members. The legal structure of the members published by TürkMMMB on its website and the areas in which each of them serves are stated on the relevant website (https://www.tmmmb.org.tr/s/54/asil-uyeler).

Although the TürkMMMB management has made publications and studies to popularize the consultancy service and increase awareness since its establishment, the importance of consultancy services in our country is still not understood, employers do not have sufficient information about what this service is and it is considered as an extra cost, therefore the scope and scope of consultancy practices are still limited. It is stated that its prevalence is extremely low (TürkMMMB, 2012; TürkMMMB, 2014a; KB, 2014).

COR service in abroad

In England and the United States, which are the leading countries in realizing the necessity of consultancy and Owner representatiton service in building production, various managerial problems began to be encountered during the project process as a result of the spread of building production, which has a special feature in terms of technology and human resources used since the early 1950s, and these problems are mainly as follows: It has been observed that it is caused by the following issues (Bayless 1986; Naoum & Langford, 1987; Minkarah & Ahmad, 1989; Haltenhoff, 1999; Mutchler & Widener, 2000; CMAA, 2003; Hess & al, 2007; CMAA, 2010; Tran & al, 2014; &):

• Insufficient number of employer employees and their level of knowledge,

• Failure to fully define the service to be provided,

• Choosing an inappropriate project delivery system,

• The design is not detailed enough,

• Insufficient scope of the contract,

• Insufficient content of the technical specifications and other specifications annexed to the contract,

• Performance problems of the parties,

• The employer makes a lot of changes,

• Failure to manage the employer/contractor's claims,

• Projects generally exceed the budget,

• Projects constantly falling behind schedule,

• The construction quality is not as expected,

• Limited participation of the employer in the design and implementation processes of the projects,

• Basing decisions and agreements made during building production on verbal statements,

• Failure to obtain products at the expected value,

• Desire to concentrate responsibility at one point.

It has been determined that a significant part of the problems listed above are employer-related; It has been observed that the employer cannot carry out the technical and managerial tasks that need to be done during the construction processes at the expected level with his own knowledge and experience without receiving technical assistance. These findings and evaluations contributed to the emergence of consultancy and employer representation practices in the construction sector in these countries. Over time, this subject has developed rapidly and gained an organizational quality, and has become flexible enough to be integrated into various project delivery systems in today's building production (Conner, 1983; Foster, 1983; Lammie & Shah, 1984; Haltenhoff, 1987; Haltenhoff, 1999; Kwak & Bushey, 2000; Bender 2004; Hess et al, 2007; Shane and Gransberg, 2010; Mahdaviparsa, Mohammad & Akbari, 2012; McKEON, 2012; Gransberg & Shane, 2013; Diao, Dong & Cui, 2018; Demetracopoulou, O’brien & Khwaja, 2020; Zhong & et al., 2023; Taheriboshrouyeh, Malindu & Sam, 2023).

Currently, construction management and owner representation services, differentiated in accordance with the project characteristics, are widely used by public institutions and the private sector, especially in the United States (Haltenhoff, 1999). COR service providers have formed various professional organizations and they play an important role in the construction industry in America. Among these organizations, the ones most accepted by employers are the AIA, the AGC, and the CMAA (Conner, 1983; CMAA, 2003; Hess et al, 2007; McKEON, 2012). In August 1975, the AIA, the AGC and the American Council of Engineering Companies (ACEC) made a joint decision and accepted consultancy and employer representation services as a separate discipline (Hess et al., 2007). Thus, the AIA and the AGC have tried to create relevant definitions and agreements on consultancy and employer representation services. In October 1981, 37 institutions consisting of contractors, engineers, architects and companies providing his services came together in Indianapolis; They established the CMAA to demonstrate the necessity and necessity of consultancy and employer representation services (Hess et al., 2007). Definitions, standards and studies related to this services have generally been handled by the AIA, AGC and CMAA organizations, their work has been accepted and the documents they have created are used effectively and widely today (Haltenhoff, 1999; CMAA, 2003). . The CMAA has created the framework for the most comprehensive study on this subject by creating definitions, application and ethical standards regarding this services. Some of the documents containing these studies are sampled below (https://www.cmaanet.org/sites/default/files/inline-files/Owners%20Guide.pdf: CM Standards of Practice)

- Contract Administration Procedures
- Cost Management Procedures
- Quality Management Procedures
- Time Management Procedures
- Agency Contract Documents Series
- CM-At-Risk Contract Documents Series
- The Profession’s Code of Ethics

- The Construction Manager in Training program-CMIT
- Certified Construction Manager-CCM®
- Organizing "Owner Forums" and "National Conferences" every year focusing on best practices in the construction industry
- Monthly Electronic Consultancy and Employer Representation Magazine and News Publications
- The CMAA Foundation
- Articles and Presentations on New Techniques and Methods
- CMAA Project Achievement Awards

Payment methods for COR Services abroad

Generally used professional COR service fee payment methods and definitions can be summarized as follows (CMAA, 2003):

- *Cost Reimbursement:* It is the frequently preferred COR service payment method, especially in public construction. Payment to be made in this method; It is determined by taking into consideration the estimated cost prepared by the company providing the COR service by calculating its own direct and indirect expenses within the scope of the service to be offered, and the rates that will be used as a basis for determining the profit. The profit of the company providing the COR service can be determined either within the estimated cost or separately from the cost. In some cases, the contract may be drawn up to take into account fixed percentage, fixed price or fixed price, incentive bonus or performance-related rewards, apart from the cost. In this context, another COR service payment method is; It is determined based on billing rates classified within the scope of personnel skills, experience and education.
- *Fixed Price:* Fixed Price payment approach; It is a form of payment that covers all COR service expenses related to the project

and in which the services to be provided and the procedures to be applied are clearly defined. It is generally applied as a different fixed price for two stages: pre-construction and construction.

- *Total cost + Fixed Price:* This payment method; It examines the expenses of the company providing COR service in two parts: project-related expenses at the project site and expenses paid to the company. For both parts, two different multipliers (coefficients) are determined to be determined in the contract as agreed by the parties.
- *Price Determined as a Percentage of Total Cost:* In this method, the COR price is stated in the contract; It is determined as a certain percentage of the project cost.Guaranteed Maximum Price: This payment method is used in delivery systems that include COR service; After a minimum of 50%-60% of the design and approximately 80% of the technical specification is completed; The project cost is determined by taking into account the estimated cost or bid cost, subcontractor contracts, tools and materials that need to be purchased from suppliers, COR service fee, other expenses related to the project and unforeseen expenses that may occur later. All expenses committed by COR can be stated as a total, or they can be determined separately as general expenses related to the project and unforeseen expenses that may occur later. For example, the expenses determined in the COR service fee should be accepted by the parties and added to the contract as an annex to the project, if the contract is concluded later. This form of payment is generally defined and paid differently in two stages: pre-production and production. While in the pre-construction phase, monthly payments can be made as fixed price, percentage of the total price, cost reimbursement or coefficients determined on the basis of worker-time, in the construction phase, the company providing COR service for the construction cost assumes the cost risk after the GEMF is determined. If COR does not assume the cost risk, the contract may be terminated completely or its pre-construction obligations in the contract will end and only COR will continue to provide services. This cost risk can be undertaken by the company providing COR services in two ways. First, the company provides only COR services, assuming the cost risk; The second can

be described as assuming the role of contractor with COR service for a certain part or all of the building production in line with the request of the employer with cost risk. This situation, in which the company providing COR services also assumes the role of contractor, is expressed as "Project Delivery System with Risk Assumption Consultancy". The most important issue in this payment method is; It is clearly defined in the contract which costs will or will not be included within the scope of GEMF. In projects where this payment method is accepted; Agreements and agreements made with contractors, subcontractors and other suppliers are carried out by the company providing COR services. These responsibilities may vary depending on the contract. In this context; It is the responsibility of the company providing COR service within the scope of the contract to remain below the maximum price upper limit guaranteed in the contract. There are two points to consider in this contract. First, what will need to be done when the potential cost is exceeded; The second is to clearly state in the contract what will be done with the remaining value if it is below cost.

In the methods mentioned above, payments to COR are made monthly based on the pre-construction work program for pre-construction and the work done by the contractor within the scope of reports for post-construction. Until final acceptance, an amount between 5% and 10% of the COR fee is kept as collateral. The amount held as collateral is paid partially during the intermediate stages of the process of obtaining an occupancy permit or after the occupancy permit is obtained.

Description and Type / Template contracts of COR

Contracts regarding COR services created by the AIA, AGC and CMAA organizations are discussed under two headings as "Project delivery system with risk-bearing consultancy" and "Consultant-project management" and are shaped in line with the needs of the employer and systematized in content. (CMAA, 2010; Mahdaviparsa, Mohammad & Akbari, 2012).

Project delivery system with risk-bearing consultancy: In this system, it refers to project delivery systems in which this services are included, the consultant also takes risks in some or all stages of the project, within the scope of the "Guaranteed Maximum Price" contract, and can also undertake the construction work depending on the agreement.

Consultant-project management: In this system, it is accepted as a construction management approach that includes this services, in which consultancy, employer representation and/or construction management are involved in the organization of building production.

It is seen that the AIA, AGC and CMAA organizations combine risk undertaking consultancy, project delivery system and Consultant-project management under the main title of "Construction Management". However, as explained above, it is understood that consultancy services are included in both systems (Haltenhoff, 1999; CMAA, 2003; Hess et al., 2007).

According to AIA; Construction management, which requires timely advice to the employer by an expert and trained person or organization on issues related to the cost impact of design and construction decisions in building production, work schedule, cost control, contract agreements and tender activities, coordination, critical tools and equipment that must be purchased on time. defines it as management services (Mutchler & Widener, 2000). Contracts related to COR services published by the AIA organization are grouped as follows (https://learn.aiacontracts.com/contract-doc-pages/21187-contract-document-series/):

- Standart Form of Agreement Beetween Owner and Construction Manager as Adviser -AIA – C132).
- Standart Form of Agreement Beetween Owner and Construction Manager as Constructor -AIA – A133 (Where the basis of payment is the cost of the work plus a fee with a guaranteed maximum price)).

According to AGC; It defines construction management as a project management system that provides coordination, administration and management in the service parts defined in the contract, within the scope of the agreement between the employer and a specialist COR service provider (https://www.agc.org/management-procurement-options).). The AGC organization currently recommends the following conventions published by their partner Construction Associations Society (ConsensusDocs) organization (https://www.consensusdocs.org/wp-content/uploads/2023/08/ConsensusDocs-All-Association-Guidebook- Aug-30-2023.pdf):

- Agreement and General Conditions Between Owner and Construction Manager (Where the CM is At-Risk) -ConsensusDocs-500.)
- Standart Owner and Construction Manager As Agent Agreement (CM Provides General Condition Items) -ConsensusDocs-830.)

CMAA; It describes construction management as a professional project management practice that aims to control time, cost, phase (project phase) and quality of construction projects from inception to completion (CMAA, 2003; CMAA, 2010). CMAA has grouped the contracts regarding COR services published by the organization as follows (https://www.cmaanet.org/bookstore):

- Standart Form of Agreement Beetween Owner and Construction Manager, CM as Owner Agent -CMAA Document A-1, 2005).
- Standart Form of Agreement Beetween Owner and Construction Manager -CM as At Risk (CMAA Document CMAR-1, 2004)).

AIA – C132, ConsensusDocs-830, CMAA Document A-1 In contracts, Construction manager; It does not take on a contractor role and can only provide consultancy and employer representation services. AIA – A133, ConsensusDocs-500 and CMAA Document

CMAR-1 In contracts, the construction manager; With the COR service, it can take on the role of contractor by providing GEMF guarantee during the construction phase.

Conclusion

As a result, it is seen that in building production in Turkey, consultancy services are still received by employers in the public and private sectors in only a very small number of construction projects, and when the entire sector is taken into consideration, the COR service remains almost non-existent. Moreover, considering the standards, procedures and relevant agreements abroad, it is clear that the consultancy services offered in our country are quite inadequate in terms of scope and quality. It is possible to say that the inadequacy in this regard is one of the most important reasons why the quality of construction in Turkey is low, there are many construction-related disputes, and most of the disputes submitted to the judiciary end in employer grievance.

Failure to implement the COR service professionally causes grievances not only to the employer but also to other stakeholders involved in building production. Because, at the design stage, the demands are not defined with sufficient scope and clarity, and at the implementation stage, the audit function cannot be fulfilled as expected and the protection of rights and interests is inadequate.

For the reasons stated, it is obvious that understanding the function of the COR service and its reflection in practice is very important in the management of construction projects in both the public and private sectors. In this context, it is essential for the COR service to prepare samples of procedures, standard contracts and specifications specific to our country, taking into account the procedures, standards and contracts determined by the relevant institutions abroad. In addition, the preparation of these documents with the contributions of professional organizations such as the Chamber of Civil Engineers, Chamber of Architects, Chamber of Contractors, Chamber of Engineers and Consultants, which are important stakeholders of building production, will enable them to be more holistic and inclusive. In addition, including the COR service legally in the legislation will increase the integration, implementation and importance of the COR service in the current system.

In this study, the COR system, one of the important tools of construction management, is summarized with its general framework in terms of scope, content and function; It was emphasized that human resources with the necessary knowledge would be needed to perform this service professionally, and by drawing attention to the inadequacy of the implementation level of these contemporary management options in our country, suggestions were presented that were hoped to contribute to eliminating this deficiency.

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CHAPTER V

Building Through Crisis: The Impact of Covid-19 on Civil Engineering Practices and Perspectives

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Introduction

From the past to the present, various events have occurred that have threatened humanity in many ways, particularly in terms of health. These events have had numerous social and economic impacts. As of the end of 2019, facing the global threat of the coronavirus pandemic, mankind, guided by the expectations arising

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from the technological and scientific advancements of the twenty-first century, initially believed that it could swiftly and effectively respond to this global menace, preventing the outbreak in a short period (Nueangnong et al., 2020). However, contrary to this expectation, the coronavirus, initially emerging locally in the Hubei region of China, rapidly escalated into a global pandemic within a very short time (Berchin & de Andrade Guerra, 2020). The emergence of COVID-19, commonly known as the coronavirus pandemic, was officially declared a global health crisis by the World Health Organization (WHO) on March 11, 2020 (World Health Organization, 2020). This declaration set in motion a series of challenges affecting businesses, governments, organizations, and societies worldwide. Since the spread of the COVID-19 pandemic to all countries, it has resulted in widespread and highly serious consequences. The economy has already been adversely affected by the COVID-19 pandemic, with many countries experiencing recession or economic slowdown. All non-essential activities, excluding vital categories such as necessities and the medical sector, have come to a halt (Ahmed et al., 2022; Gamil & Alhagar, 2020). The construction industry, a critical component of global economies, was no exception to the widespread impacts of the pandemic (Pamidimukkala & Kermanshachi, 2021).

In response to the crisis, many countries declared states of emergency, closed borders and imposed travel restrictions to curb the spread of the virus. Unsurprisingly, these measures had a profound effect on construction activities, leading to disruptions such as material shortages due to supply chain interruptions, labor, and skill shortages, and, in some cases, the complete suspension of construction projects (Majumder & Biswas, 2021; Rokooei et al., 2022). The implemented restrictions reverberated across all stakeholders in construction projects, resulting in severe financial consequences. Companies across various sectors were compelled to adopt measures to ensure business continuity, supply chain flexibility, and innovative revenue-generation strategies (Iqbal et al., 2021).

The uncertainties stemming from the pandemic significantly influenced the field of civil engineering. Despite the challenges posed by COVID-19, some construction engineering activities persisted, particularly in countries where complete shutdowns were not implemented. In such instances, companies remained willing to execute their contracts to mitigate financial losses (Research and Markets, 2020). The legal solutions available to parties in construction contracts to protect their rights and minimize losses depend on the specific conditions outlined in their contracts (Nina Jankovic, 2020).

In the private sector, construction project delays were observed as investors redirected funds from projects. Losses in 2020 revenues throughout the construction process led to the postponement or cancellation of future projects (Sam Potts, 2020). The global construction market was anticipated to shrink from $11,217.4 billion in 2019 to $10,566.8 billion in 2020, with signs of recovery expected in 2021, reaching a market size of $11,496.7 billion (Research and Markets, 2020). Anticipated industry constraints included the closure of production facilities, shortages of raw materials, and limitations on growth due to supply chain and logistics disruptions (Research and Markets, 2020).

Shifting the focus to Türkiye, the construction sector, a key player in the country's economy, faced unique challenges brought about by the global pandemic. This sector, vital for employment generation and economic development, witnessed slowdowns on construction sites, with firms exploring alternatives such as rotational shifts and remote work to maintain operations (Soner Keleş, 2020). Measures to prevent virus spread in sales offices and construction sites significantly disrupted construction sector operations. The reduced demand for real estate due to people staying at home during the pandemic further strained the industry. Supply chain issues led to project delays decreased consumer satisfaction and trust, and financial challenges for developers and contractors (Soner Keleş, 2020).

Against the backdrop of global economic developments and uncertainties resulting from the COVID-19 pandemic, the construction sector in Türkiye encountered a complex set of challenges. Factors such as global liquidity conditions, geopolitical risks, currency exchange rates, oil prices, public finance, and an unpredictable interest rate equation influenced an industry that was among the hardest hit by the pandemic. Despite being a driver of demand across more than 200 sub-sectors, the construction industry in Türkiye experienced continued contraction, reducing its share of the GDP from 7.2% to 5.4%. The Turkish Statistical Institute (TUIK) reported a contraction of 8.6% in the construction sector, contrasting with the overall GDP growth of 0.9% in 2019. In April, the construction sector saw a sharp decline in the confidence index due to the impact of the COVID-19 outbreak, dropping by 35.9 points compared to the previous month, reaching its second-lowest level in recent years (Türkiye IMSAD, 2020).

The COVID-19 pandemic not only reshaped the operational landscape of various sectors but also prompted the field of civil engineering to embrace digital software applications and optimize remote work where feasible. Advancements in digital technologies are expected to play a crucial role in helping the sector cope with future pandemics and global disasters, enhancing resilience and adaptability.

This study aims to unravel the multifaceted challenges, adaptations, and innovations faced by civil engineers during these tumultuous times. The construction sector, known for its resilience and adaptability, found itself navigating uncharted waters as lockdowns, supply chain disruptions, and social distancing measures took center stage. Civil engineers, the backbone of construction projects, were compelled to reassess traditional methodologies, recalibrate timelines, and develop novel strategies to ensure the continuity and safety of ongoing projects. This study centers on acquiring insights using a survey carried out with both working and unemployed civil engineers. Through firsthand experiences and perspectives of civil engineers who weathered the storm, this study seeks to provide a comprehensive examination of the pandemic's effects on the construction industry. In addition, as part of a survey conducted among unemployed civil engineers (those who are not currently working in any engineering profession - unemployed, job seekers/not seeking, or those who have resigned from their jobs), the attitudes, behaviors, thoughts, and psychological states of the respondents (unemployed civil engineers) during the pandemic were investigated.

Method

The survey was conducted during the COVID-19 Pandemic. The focus group of this study was divided into two; Group 1: employed and Group 2: unemployed civil engineers during the COVID-19 pandemic. This research utilized a survey tool created with the Google Forms application to investigate the impact of the COVID-19 pandemic on employed and unemployed civil engineers. The study focuses on gathering insights through a survey conducted with 56 working civil engineers and 51 unemployed young civil engineers. Respondents comprised civil engineers in various cities across Türkiye. The survey questions were meticulously designed to capture firsthand experiences, challenges, and coping strategies employed by civil engineers (employed and unemployed) during this challenging period.

In this survey, a total of 55 questions were presented to employed civil engineers and 50 questions to unemployed civil engineers. The first five of the questions asked to both groups were the same and they were targeted to gather information about the demographic features of the responders. The rest of the questions were completely different from each set of questions asked for the two groups. The survey questions used in this study are given in the appendix.

The survey questions for Group 1 were structured to gather information systematically, organized as follows:

Questions 1-5 were aimed at understanding the demographic profile of the respondent.

Questions 6-7 focused on whether the respondent worked from home or had flexible working conditions, and if so, the perceived benefits.

Questions 8-12 delved into the respondent's thoughts on their personality, motivation, and any challenges faced in terms of mental, financial, and health aspects.

Questions 13-32 inquired about the respondent's workplace, including adherence to rules and regulations, health and safety training, company initiatives, and potential challenges.

Questions 33-38 examined hygiene and social distancing measures at the respondent's worksites, addressing labor-related issues and any hindrances in completing projects.

Questions 39-44 focused on the status of the respondent's projects, including delays, legal issues, project approval, and timely payment.

Questions 45-55 were designed to gauge satisfaction with the attitudes and approaches of the government, employers, colleagues, and the overall management of the workplace during the pandemic.

The survey questions for Group 2 were structured to gather information systematically, organized as follows:

Questions 1-5 are asked to gather information about the respondent's demographic features.

Questions 6-7 aim to investigate whether the respondent was unemployed during the pandemic, and if so, whether the pandemic had an impact on their unemployment.

Questions 8-10 assess whether the respondent, due to being unemployed, made job applications during the pandemic and if they worked in a profession other than their own.

Questions 11-21 inquire about the financial difficulties, job search challenges, self-improvement during unemployment, willingness to work in another city, the impact of restrictions on job opportunities, and feedback from job applications received during unemployment.

Questions 22-27 are related to the respondent's dismissal from employment. They aim to understand whether the respondent was laid off due to the downsizing or closure of the company or business, the reasons for termination, and whether the termination was temporary or permanent.

Questions 28-33 investigate the reasons for the respondent's voluntary departure from employment (self-improvement, working in a higher-paying job, family's request, health issues, working conditions, irregular salary payments, etc.).

Questions 34-45 explore the respondent's perspective on the reasons for unemployment and its effects on their life (limited job opportunities, favoritism, inadequate education). Additionally, they inquire about the mental impact of unemployment, disappointments related to their profession, and the impact on relationships with family and the surrounding community.

Questions 46-50 are satisfaction-related questions. They aim to learn about the respondent's satisfaction with employer attitudes and behaviors, job opportunities, and relationships with family and the surrounding community.

Results of the Surveys

Figure 1 compares the age distribution, marriage status, and working conditions of the spouses for the two groups. The distribution of ages among the 56 employed (Group 1) civil engineers revealed that 46.4% are aged 30 and below, with 23.2% falling within the 30-40 age bracket, 14.3% in the 40-50 range, and 16.1% aged 50 and above. In terms of gender, the survey identified that 58.9% of participants are male, while 41.1% are female.

Among the participants in Group 1, marital status revealed that 37.5% are married, while 62.5% are not married. In the context of marital relationships, 17.9% of respondents have employed spouses, 19.6% have spouses who do not work, and 62.5% are not married. Family demographics further illustrate that 60.7% of respondents do not have children, 14.3% have one child, 19.6% have two children, and 5.4% have three or more children.

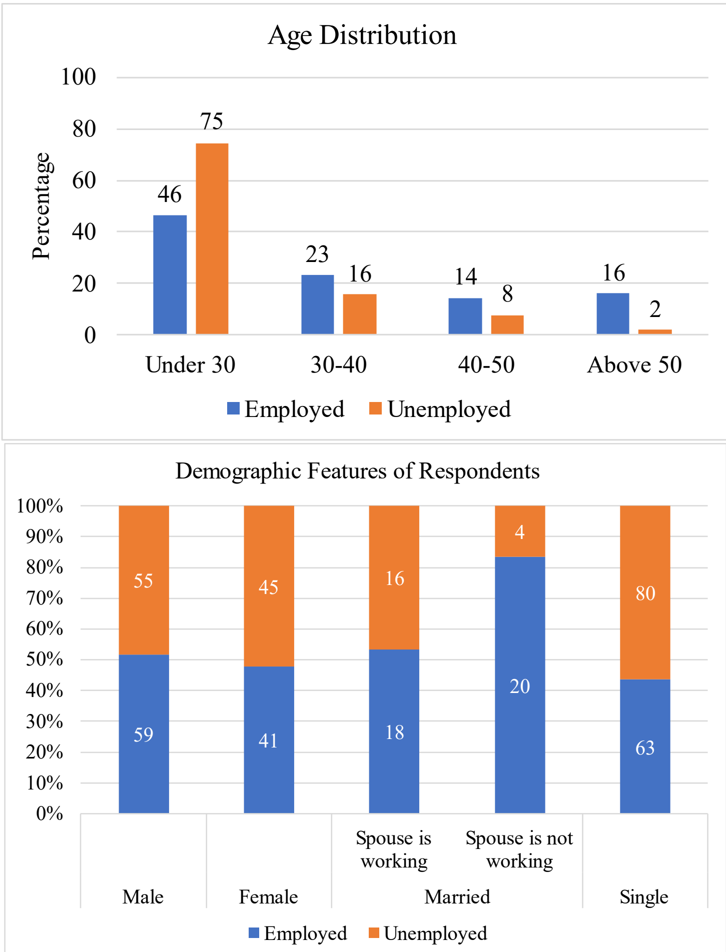

Figure 1. Age distribution and demographic features of employed and unemployed civil engineers

The survey findings from 51 unemployed young civil engineers (Group 2) reveal a diverse demographic composition. A significant 75% are under 30 years old, 16% fall within the 30-40 age range, 8% are in the 40-50 age bracket, and a solitary individual (2%) is aged 50 and above. In terms of gender, 28 respondents are male, reflecting a higher male representation attributed to the preferences within the chosen field. Marital and parental statuses provide insights, with 41 being unmarried, 8 having a working spouse, and 2 having a non-working spouse. Additionally, 42 participants have no children, while 5 have one child, and 4 have two. Pandemic-induced unemployment affects 31 individuals directly, with 18 facing partial unemployment due to business closures or downsizing. The perception of 35 respondents is that their unemployment is pandemic-related, while 16 individuals (31.4%) believe otherwise, often citing the widespread layoffs during the pandemic as a contributing factor.

Other findings related to challenges faced and the satisfaction levels towards the inspected questions for each group are investigated separately and the summarized results are given in the following sections.

GROUP 1: Employed Civil Engineers During the Pandemic

The comprehensive survey conducted among 56 participants offers significant insights into the work arrangements, challenges faced, and satisfaction levels among civil engineers during the COVID-19 pandemic.

Work Arrangements and Perceptions:

Work arrangements during the pandemic reveal a diverse landscape, with 10.7% working from home, 28.6% at their workplace, and 60.7% adopting flexible arrangements. The preference for flexibility is associated with individual preferences, while the perception of working from home is split, with 42.9%

expressing benefits and 57.1% indicating no advantages, emphasizing the psychological impact experienced during remote work.

Challenges Faced:

Challenges faced during the pandemic are multifaceted, with 80.4% of respondents encountering difficulties, primarily attributed to material and spiritual hardships. Notably, 60.7% report engaging in personal development efforts, demonstrating a proactive response, while 39.3% find it challenging to enhance their skills and knowledge. Psychological challenges are prevalent, affecting 76.8% of respondents, and financial concerns impact 46.4%, highlighting the economic strain on a significant portion.

Health, Hygiene, and Social Distancing:

In terms of health, 39.3% of respondents faced health-related challenges, while a majority of 60.7% did not encounter health difficulties. Adherence to hygiene rules in the workplace is notable, with 75% confirming compliance, but 25% reporting non-compliance. Social distancing rules are followed by 64.3%, while 35.7% observe non-compliance, providing insights into the challenges faced in maintaining safety measures.

Workforce, Economic, and Government Support:

Workforce shortages are experienced by 55.4%, while 57.1% report shortages in human resources. Economic challenges are encountered by 53.6%, and 26.8% receive government assistance, highlighting the need for additional support mechanisms.

Project Management and Productivity:

Project-related challenges include 64.3% facing difficulties in completing their construction sites on time and 73.2% facing delays. In terms of productivity, 32.1% note an increase, while 67.9% report no change.

Knowledge and Education:

Satisfaction with knowledge and education gained shows varied responses, with 3.6% highly satisfied, 14.3% satisfied, 39.3% partially satisfied, 32.1% dissatisfied, and 10.7% not satisfied at all.

GROUP 2: Unemployed Civil Engineers During the Pandemic

The survey findings from 51 participants reveal significant insights into the economic challenges, perceptions in the workplace, and reasons behind unemployment among unemployed civil engineers during the COVID-19 pandemic.

Economic Challenges:

Economic challenges are prevalent, with 92.2% experiencing financial difficulties, whereas 7.8% declare support from family, government, or other sources. Notably, 18 individuals have received government support, while the rest have not or cannot. Financial support from families is split, with 33 receiving assistance and 18 managing without. A small percentage (13.7%) resorted to bank loans, while the majority (86.3%) did not. Furthermore, 96.1% of respondents believe that unemployment's psychological impact is significant, attributing it to both job loss and financial constraints.

Professional Perceptions:

In terms of professional perspectives, 92.2% express disappointment in their careers, with a similar percentage facing challenges in finding job opportunities. Only 7.8% have ventured into entrepreneurship, mainly hindered by financial constraints. The pandemic has prompted 90.2% to self-improve, while 9.8% found it challenging to do so, often due to perceived limitations in available free time. The duration of unemployment is perceived differently, with 13.7% considering it short-term and 86.3% as a long-term challenge. A notable finding is that 16% attribute their unemployment to their age, often related to being recent graduates without sufficient experience for certain job requirements.

Reasons Behind Unemployment:

The survey delves into the reasons behind job losses, with 26% blaming their departure on disagreements with their employers, 47% attributing it to a lack of foreign language proficiency, and 53% citing various other reasons. For some, leaving their jobs presented an opportunity for self-improvement (25.5%), while others cited family concerns (10%) or personal health issues (10%) as motivating factors. A substantial 33% left to seek higher-paying jobs, 45% due to irregular salary payments, and 18% because of unhealthy working conditions. The overwhelming consensus is that unemployment has negatively impacted life conditions, with 90% citing both financial and emotional reasons. The limited availability of job opportunities (82%) and the inadequacy of public sector openings (82%) are predominant reasons for unemployment. Furthermore, 26% attribute their unemployment to insufficient education, while 11.8% blame dissatisfaction with working conditions.

Perceptions in the Workplace:

Perceptions of favoritism and nepotism in the workplace are prevalent, with 51% believing that unfair workplace practices contribute to unemployment. Additionally, 51% feel that unemployment affects family relationships, and 45% perceive an impact on social circles. A striking 92.2% assert that unemployment has altered their professional aspirations, with many believing that pursuing a different career path could offer better job prospects. Notably, 71% express readiness to work in another city if job opportunities arise. Of the respondents, 65% received feedback, either positive or negative, on their job applications. However, 73% struggle to meet their basic needs.

Challenges:

The pandemic has introduced further complexities, with 90% believing that restrictions and lockdowns have made job hunting more challenging. A substantial 84% attribute their inability to find work to the contraction in the construction sector. While 29% are partially satisfied with job opportunities, 70.1% express dissatisfaction, with no respondents reporting overall satisfaction. Similarly, job dissatisfaction extends to employer behaviors, with 28% expressing partial satisfaction and 72% overall dissatisfaction. On the personal front, 43% express satisfaction with family relationships during the pandemic, while 55% are partially satisfied, and only 2% report dissatisfaction. Regarding relationships with their surroundings, 26% expressed satisfaction, and 74% partial satisfaction, with no respondents reporting dissatisfaction. In summary, the survey paints a detailed and nuanced picture of the challenges, perceptions, and experiences of individuals grappling with unemployment, providing valuable insights into the multifaceted impact of this complex phenomenon.

Discussion

Discussion on the Results of Group 1:

The findings from this survey shed light on the profound impact of the COVID-19 pandemic on the construction sector, particularly from the perspective of employed civil engineers. The notable surge in remote work, experienced by over half of the respondents, has unveiled both challenges and opportunities. Surprisingly, a significant majority, 80.4%, faced difficulties with remote work, highlighting the need for tailored strategies to address the unique demands of the construction profession in a remote setting.

The prolonged duration of remote work has not only altered work dynamics but has also taken a toll on the psychological well-being of employed civil engineers, as reported by 76.8% of the respondents. This underscores the importance of implementing supportive measures and mental health initiatives within the construction industry to mitigate the adverse effects of remote work and uncertainty of future related plans in such hard times on individuals.

While hygiene and social distancing measures became prevalent across construction workplaces, the survey exposes a gap in providing necessary training, with 76.8% of the workplaces neglecting this crucial aspect. The absence of psychological support, indicated by 83.9% of respondents, further emphasizes the need for comprehensive employee assistance programs tailored to the construction sector.

Labor shortages (55.4%) and economic challenges (53.6%) have posed significant hurdles for construction workplaces, hindering the sector's ability to navigate the pandemic smoothly. Despite proactive planning in a majority of workplaces (66.1%), the expected surge in productivity did not materialize for most respondents (67.9%).

Flexibility in working hours, introduced by 73.2% of workplaces in response to the limitations on extended working hours, emerged as a positive adaptation. Additionally, the accelerated adoption of digitalization witnessed in 60.7% of workplaces, signifies a transformative shift in the construction industry's operational landscape.

Challenges in material procurement (67.9%) and partial satisfaction with workplace direction (51.8%) underscore the need for resilient supply chain strategies and strategic planning to optimize workplace efficiency.

Construction sites, while generally adhering to hygiene (58.9%) and social distancing rules (67.9%), faced difficulties in project completion, with 64.3% reporting challenges within specified timelines. The majority of civil engineers (82.1%) encountered delays in their projects, yet a positive aspect is a significant majority (82.1%) who received compensation for their efforts.

Discussion on the Results of Group 2:

The demographic breakdown paints a vivid picture of unemployed civil engineers, revealing a predominantly youthful profile, with a substantial 75% of respondents falling under the age of 30. This youthfulness in the survey's participants may underscore the broader trend of younger professionals entering the workforce, particularly in the field of civil engineering.

Economic challenges emerge as a prevailing theme, with a substantial 92.2% of respondents reporting financial difficulties. The role of support systems, including familial and governmental support, comes to the forefront, revealing the interconnectedness of personal and external factors in navigating periods of unemployment. The psychological impact of unemployment is a shared concern among participants, emphasizing the need for holistic support measures that extend beyond financial assistance.

From a professional standpoint, disappointment in careers and challenges in finding job opportunities permeate the survey results. Entrepreneurship, albeit embraced by a minority, faces hindrances primarily rooted in financial constraints. The pandemic catalyzes self-improvement among a significant number of respondents, showcasing the resilience and adaptability of the surveyed group in the face of adversity.

Noteworthy findings include the diverse perspectives on the duration of unemployment, with a considerable 86.3% perceiving it as a long-term challenge. The survey delves into the multifaceted reasons behind job losses, revealing a spectrum of factors, including disagreements with employers, language proficiency issues, and various other reasons. The impact on life conditions is significant, with 90% citing both financial and emotional reasons for the negative effects of unemployment.

Conclusion

The synthesis of findings from two distinct surveys, one focused on employed civil engineers and the other on their unemployed counterparts, provides a comprehensive understanding of the multifaceted impact of the COVID-19 pandemic on the civil engineering sector. The employed engineers' survey reveals the seismic shift in work dynamics induced by the pandemic, with remote work emerging as both a challenge and an opportunity. The toll on psychological well-being, the need for tailored strategies for remote work, and the gaps in training and psychological support within construction workplaces highlight the urgent necessity for holistic employee assistance programs.

Labor shortages, economic challenges, and disruptions in supply chains have posed significant hurdles for construction workplaces, underscoring the need for resilient strategies. On a positive note, the flexibility in working hours, increased digitalization, and compensation for project delays signify adaptive responses to the challenges faced by employed civil engineers.

The survey among unemployed civil engineers provides a poignant glimpse into the struggles faced by young professionals, particularly in Türkiye. Economic challenges dominate, with financial difficulties reported by a staggering majority. The survey highlights the interconnectedness of personal and external factors, emphasizing the need for comprehensive support measures beyond financial assistance. The impact on mental health, disappointment in careers, and challenges in finding job opportunities further underscore the need for holistic interventions.

The demographic breakdown of the unemployed engineers, with a predominant youthful profile, suggests broader trends in the industry. Gender disparities and the diverse personal circumstances of respondents emphasize the importance of considering individual situations in discussions surrounding unemployment. The survey also delves into the intricate reasons behind job losses, providing valuable insights for policymakers and employers to address issues such as favoritism and nepotism in the workplace.

In conclusion, this study offers a perspective on the challenges faced by civil engineers during the pandemic, encompassing both the employed and unemployed segments. The findings underscore the need for adaptable strategies, comprehensive support mechanisms, and targeted interventions to navigate the complexities introduced by the pandemic. As the industry evolves, the insights provided by these surveys serve as valuable guides for policymakers, employers, and educators in crafting effective strategies to support and enhance the well-being of civil engineers in both their employed and unemployed states.

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APPENDIX 1

Questions asked for Group 1 (employed civil engineers during the pandemic):

1. How old are you?

2. What is your gender?

3. Are you married?

4. If married, is your spouse employed?

5. How many children do you have?

6. Did you work from home during the pandemic?

7. Was there any benefit to working from home during the pandemic?

8. Did you face difficulties during the pandemic?

9. Did you engage in self-development during the pandemic?

10. Did you experience psychological challenges during the pandemic?

11. Did you face financial challenges during the pandemic?

12. Did you face health-related challenges during the pandemic?

13. Were hygiene rules followed at your workplace during the pandemic?

14. Were social distancing rules followed at your workplace during the pandemic?

15. Did your workplace undergo any downsizing during the pandemic?

16. Did your employer pay your salary on time during the pandemic?

17. Did your workplace provide health-related training during the pandemic?

18. Did your workplace provide psychological training during the pandemic?

19. Did your workplace conduct COVID-19 testing for employees?

20. Did your workplace experience a shortage of labor during the pandemic?

21. Did your workplace experience a shortage of manpower during the pandemic?

22. Did your workplace face economic difficulties during the pandemic?

23. Did your workplace receive government assistance during the pandemic?

24. Did your workplace make future plans during the pandemic?

25. Did your workplace effectively manage the pandemic situation?

26. Did the productivity of your workplace increase during the pandemic?

27. Were working hours flexible at your workplace during the pandemic?

28. Did your workplace take adequate precautions to prevent accidents?

29. Did your workplace transition to digital processes during the pandemic?

30. Did your workplace experience difficulties in material procurement during the pandemic?

31. Did your workplace face challenges due to rising material prices during the pandemic?

32. Did employees leave your workplace due to health reasons during the pandemic?

33. Were hygiene and social distancing rules followed at offices, sites, and construction sites during the pandemic?

34. Did your workplaces stop during the pandemic?

35. Did you face challenges with workers on your sites or construction sites during the pandemic?

36. Did you experience a shortage of manpower on your sites or construction sites during the pandemic?

37. Did you face difficulties in completing your projects on time during the pandemic?

38. Did you face time constraints in your projects and work during the pandemic?

39. Did your projects face delays during the pandemic?

40. Did you face legal proceedings due to delays in your projects during the pandemic?

41. Were your projects put on hold during the pandemic?

42. Were you able to receive payment for your projects during the pandemic?

43. Are you satisfied with the government's approach during the pandemic?

44. Are you satisfied with your employer's approach during the pandemic?

45. Are you satisfied with your colleagues' approach during the pandemic?

46. Are you satisfied with your employer's adherence to rules during the pandemic?

47. Are you satisfied with your colleagues' adherence to rules during the pandemic?

48. Are you satisfied with how your workplace managed the pandemic situation?

49. Are you satisfied with the overall direction of your workplace during the pandemic?

50. Are you satisfied with the potential of your workplace to carry out its activities during the pandemic?

51. Are you satisfied with your workplace's approach to digital transformation during the pandemic?

52. Are you satisfied with your projects and work during the pandemic?

53. Are you satisfied with the knowledge and skills you gained during the pandemic?

54. Are you satisfied with the information you gained from the projects and work you carried out during the pandemic?

APPENDIX 2

Questions asked for Group 2 (unemployed civil engineers):

1. How old are you?
2. What is your gender?
3. Are you married?
4. If married, is your spouse working?
5. If married, how many children do you have?
6. Were you unemployed during the pandemic?
7. Was your job lost due to the pandemic?
8. Did you apply for jobs during the pandemic?
9. Did you work in a profession other than civil engineering during the pandemic?
10. Would you consider working in a different field than civil engineering during the pandemic?

11. Did you face economic difficulties during the pandemic?

12. Did you receive support from the government during the pandemic?

13. Did you receive support from your family during the pandemic?

14. Did you take out a loan from the bank during the pandemic?

15. Did you face difficulties in finding job opportunities during the pandemic?

16. Did you improve yourself while unemployed during the pandemic?

17. Would you accept a job in another city during the pandemic?

18. Did you receive feedback from your job applications during the pandemic?

19. Did you struggle to meet your basic needs during the pandemic?

20. Did the pandemic restrictions affect your job search?

21. Did you fail to find a job due to the slowdown in the construction sector during the pandemic?

22. If you were laid off during the pandemic, was it due to your company or organization downsizing?

23. If you were laid off during the pandemic, did your company or organization close?

24. If you were laid off during the pandemic, was it temporary?

25. If you were laid off during the pandemic, was it due to your age?

26. If you were laid off during the pandemic, was it due to a disagreement with your boss?

27. If you were laid off during the pandemic, was it due to a lack of proficiency in a foreign language?

28. If you left your job during the pandemic, was it to improve yourself?

29. If you left your job during the pandemic, was it because your family wanted you to?

30. If you left your job during the pandemic, was it due to health reasons?

31. If you left your job during the pandemic, was it to work in a higher-paying job?

32. If you left your job during the pandemic, was it due to irregular salary payments?

33. If you left your job during the pandemic, was it because you worked in an unhealthy environment?

34. Did being unemployed during the pandemic affect your psychology?

35. Did being unemployed during the pandemic cause disappointment in your profession?

36. Did being unemployed during the pandemic affect your living conditions?

37. Is being unemployed during the pandemic due to limited job opportunities?

38. Did you start your own business due to being unemployed during the pandemic?

39. Is being unemployed during the pandemic due to a lack of job openings?

40. Is being unemployed during the pandemic due to the inadequacy of your education?

41. Is being unemployed during the pandemic due to not liking the available jobs?

42. Is being unemployed during the pandemic due to favoritism?

43. Did being unemployed during the pandemic affect your relationship with your family?

44. Did being unemployed during the pandemic affect your relationship with your friends?

45. Did being unemployed during the pandemic change your thoughts about your profession?

46. Are you satisfied with job opportunities during the pandemic?

47. Are you satisfied with the contributions made by the government during the pandemic?

48. Are you satisfied with the behavior of employers during the pandemic?

49. Are you satisfied with your relationship with your family during the pandemic?

50. Are you satisfied with your relationship with your friends during the pandemic?

CHAPTER VI

Using Pumice at Road Pavement Construction in Different Aspects

Muhammed TANYILDIZI[1]
İslam GÖKALP[2]

1-INTRODUCTION

Pumice is a porous lightweight material of volcanic origin formed during the rapid solidification of molten lava (Kabay et al., 2015). It is mostly composed of silica and alumina in relative amounts that vary according to the geological area of origin and also contains other chemical components including different oxides and water (Deganello et al., 1998; Tanyıldızı and Gökalp, 2023). The cellular structure and lightness of pumice are due to the formation of

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bubbles or air voids by trapping the gases inside the molten lava while it cools (Ersoy et al., 2010; Gencel, 2015). The pores inside the pumice structure are parallel or elongated or sometimes connected (Hossain, 2004). The size of the pore could be in small and big sizes (Saltan and Fındık, 2008). It can be found especially in regions with volcanic activity such as Turkey, the USA, Greece, Italy, and Spain (Cavaleri et al., 2003). There are approximately 18 billion tons of pumice deposits in the world. The USA, Turkey and Italy host approximately 11.5, 2.8 and 2.5 billion tons of it which corresponds to 90.8% of the world's total reserve. The chemical characteristics of the pumice are the most important factor in the emergence of its color. The acidic pumice's color is white or gray, basic pumice's is gold to dark brown. The acidic pumice has a very porous structure and its specific gravity changes between 0.5-1 g/cm^3. Basic pumice is heavier than acidic one and its specific gravity varies between 1-2 g/cm^3. SiO_2 is the main oxide of pumice and it forms around 50-90% of a pumice structure. Al2O3 and Fe_2O_3 are other oxides following SiO_2 in terms of content, respectively (Akkurt and Akyıldırım, 2012; Değirmenci and Yılmaz, 2011; Elmastaş, 2012; Zeyad et al., 2019).

The most common type of pumice encountered worldwide is acidic pumice (Gündüz et al., 1998; Yücel et al., 2020). A typical acidic and basic pumice are presented in Figure 1 (*Pomza Curuf*, 2023; *Pumice*, 2023).

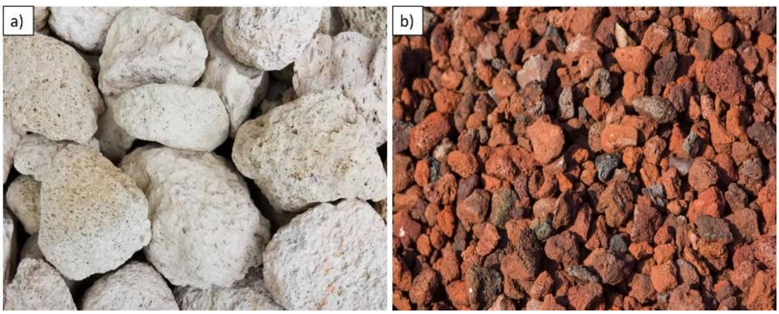

Figure 1. Typical acidic (a) and basic (b) pumice

Although pumice generally is utilized as aggregate in lightweight concrete production in most countries around the world due to its many prospective properties such as low density, reasonable elasticity, porous structure with low permeability, acceptable compressive strength, and non-combustibility (Hossain, 2004; Rashad, 2019), its usage area is considerably wide and can be utilized as a denim grinding material on textile (Kan, 2015) as a decorative and flooring material in architecture (Canbolat et al., 2015), as a filter material to regulate the air and water permeability in the soil in agriculture (Boyraz and Nalbant, 2015), as polishing cake in toothpaste and an additive in the cleaning and detergent in chemistry (Kitis et al., 2007), as an additive in facial and body scrubs as a manual exfoliant in cosmetics (Hoffer, 1994), and as a chemical stabilizer in expansive pavement subgrade stabilization (Saltan et al., 2011).

This paper was established on the studies performed on the usage of pumice in the construction of road structures. Pumice has served different purposes in road construction and is utilized as a sub-grade or subbase material, as aggregate or fiber in hot-mix asphalt, as lightweight aggregate, or mineral additive in rigid pavement. The studies reviewed here are categorized and divided into three sections: geotechnical, flexible pavement and rigid pavement throughout the utilization of pumice in road structure main title. In addition, with this study, it was aimed to inform both researchers and sector representatives and to raise awareness about the use of pumice for different purposes in road construction.

2. UTILIZATION OF PUMICE IN ROAD STRUCTURE

A road is a structure constructed for the conveyance of traffic, with a surface developed for use mostly by motorized or non-motorized vehicles and pedestrians. Construction of roads requires a certain designing phase and placing several different layers during practice in the field. A road structure built on a subgrade consists of three main structural elements: surface layer, base layer and subbase layer as seen in Figure 2.

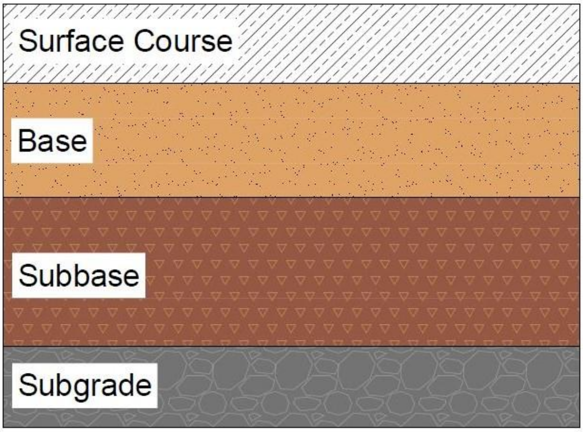

Figure 2. *Section of a typical road*

The subgrade is the substructure of a road that involves a cut and fill process. The subbase, base and surface courses form the superstructure of a road, which transfers the traffic loads to the subgrade soil (Plati and Cliatt, 2018). Subgrade can be a natural soil or a stabilized one with sufficient bearing capacity and durability to withstand the load from superstructure and detrimental environmental effects (Kumar and Singh, 2023). Subbase is a superstructure layer composed of granular materials, constructed to support the base layer and safely transfer loads to the subgrade (Sağlık et al., 2006). The base is a layer constructed at a certain thickness above the subbase layer to support the surface layer by distributing the loads, ensure good drainage and reduce the freeze-thaw effect (Su et al., 2017). The surface course is the upper layer of a road structure that is constructed with bituminous mixtures or cement concrete which is directly exposed to traffic (Mohod and Kadam, 2016). The satisfactory performance of a road structure depends on its structural elements being well designed and constructed to high quality. For this reason, materials with superior properties that will serve the desired functions have started to be looked for as an alternative to conventional materials. Some of these alternative materials are stone dust (Mishra et al., 2019), waste glass (Xiao et al., 2020), crumb rubber (Zheng et al., 2021), recycled concrete aggregate (Fanijo et al., 2023) and waste marble (Khan et al., 2023), etc.

Pumice is one of these materials that has been used in road construction to improve the engineering properties of a road structure. However, studies on the usability of pumice in road construction are limited and more studies are needed to reveal the possibility of pumice serving this purpose. This study herein focuses on studies investigating the usability of pumice for different purposes in road construction. So, the studies are divided into geotechnical, hot mix asphalt and rigid pavement sections and presented in the following sections.

3. USE OF PUMICE IN ROAD GEOTECHNICAL APPLICATIONS

The geotechnical components of a road structure are generally identified with the subgrade, subbase and base layers (Omorogieva and Okiti, 2022). These layers directly affect the cost and service life of a road structure. The choice of material used in these layers is critical to achieving a road with high strength and durability. Therefore, sometimes traditional materials may need to be stabilized or replaced with any material that performs relatively better in the desired conditions. In light of current studies, this aspect will be indicated in the following.

Saltan and Fındık (2008) performed a study to improve the engineering properties of a local subbase material with pumice and analyzed the cost effect of stabilization. The local subbase material was replaced with pumice in ratios 20%, 25% and 30% and consistency limits and the bearing capacity of mixtures were evaluated by conducting California Bearing Ratio (CBR) test. The test results revealed that the CBR of local subbase material increased from 79% to 91.295%, 109.6% and 125.595% with 20%, 25% and 30% pumice ratios, respectively. In addition, plasticity index (PI) and liquid limit (LL) of local subbase material decreased with the pumice ratio as shown in Figure 3. It was also reported that 53%

profit could be achieved through the stabilization of local subbase material with pumice.

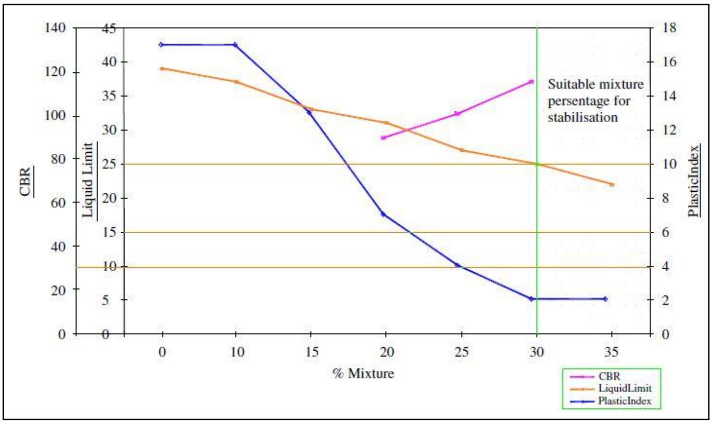

Figure 3. Change in engineering properties of local subbase material with pumice

Shiferaw (2020) made an experimental analysis to investigate the suitability of lime-treated pumice as a subbase material. The author stated that the CBR value of volcanic pumice aggregate was significantly improved, more than doubling when blended with 6% lime and achieved the required strength as a subbase material. In a different study, Saltan et al. (2011) utilized pumice for the stabilization of a clayey subgrade. A serial analysis consisting of consistency limits, CBR and resilient modulus (M_r) tests were conducted to reveal the efficiency of pumice on the stabilization process. The test results from the experimental analysis indicated that the PI of the clayey subgrade reduced with an increase in pumice content. The CBR of subgrade enhanced consistently with pumice content and it reached from 6.78% to 10% with a 40% ratio. In addition, an increase in the M_r of 240–250 MPa was obtained through the stabilization process. The authors reported from the test results that adding 40% pumice during construction is more beneficial for clay soil stabilization than removing clay soil.

Crucho et al. (2021) made a study to investigate the performance of cement-treated basaltic pumice (scoria) as a subbase or base material in road construction through unconfined compressive strength (UCS) test. Cement was used to treat the pumice in the ratio of 5% by dry weight and two different curing durations of 7 and 28 days were applied to the specimens. It was revealed that the UCS value increased with cement and increasing curing durations, which provided the usability of cement-treated basaltic pumice as a subbase or base material in road construction. Smaida et al. (2021) carried out a study to improve the engineering properties of dune sand with combinations of pumice and lime for the pavement base application. The dune sand was replaced with pumice and lime combinations in different ratios of 10%, 15%, 20% and 25%. The proportion of pumice to lime was 4% in each additive ratio. The author declared from the test results that the engineering characteristics including CBR, shear strength and tensile strength of dune sand improved with pumice and lime addition. In addition, it was stated that both 16% pumice and 4% lime and 20% pumice and 5% lime combinations together with dune sand are the optimum ratios for pavement foundation application.

In another study, Çimen et al. (2015) replaced expansive clayey subgrade with pumice in various ratios (0-50% with 10% increments) to improve its engineering properties. The change in the properties of the subgrade of this study is shown in Figure 4. It was reported that the UCS and CBR of subgrade increased with up to 30% and 40% pumice addition, respectively. In addition, the swelling potential decreased continuously with pumice content.

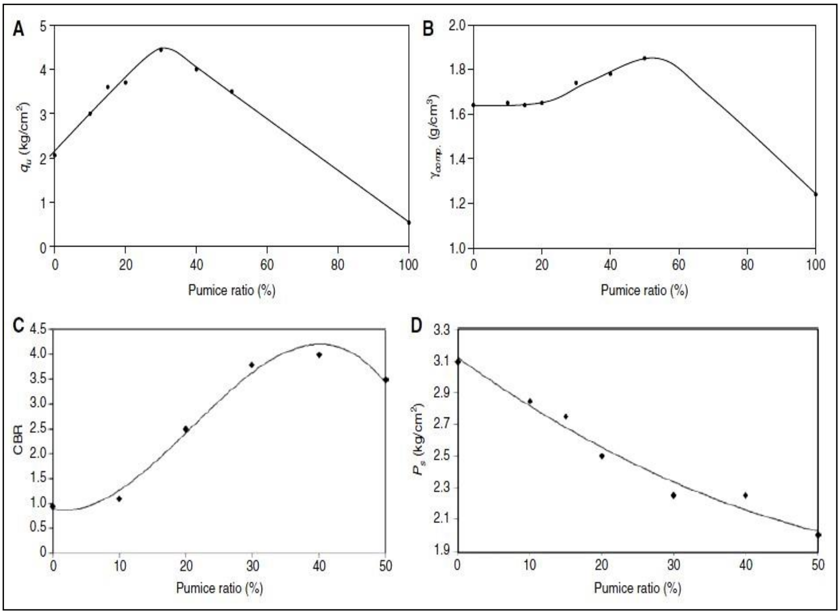

Figure 4. Change on the engineering properties of expansive subgrade with pumice content

Mesfun et al. (2019) evaluated the effect of pumice with lime on the stabilization of expansive pavement subgrade. The various lime and pumice combinations were tried in experimental analysis and it was stated that the combination of 3% pumice and 7% lime improved the CBR value and decreased the swelling potential of subgrade. In a similar study done by Dercha (2021) for stabilizing expansive subgrade. To achieve it, equal amounts of mixtures of crushed stone dust and pumice were used for the stabilization of the subgrade. The result of the study showed that CBR value of expansive subgrade increased consistently with increasing pumice and crushed stone dust content. The increase in the CBR value of expansive subgrade was associated with the improvement of compactness of the mixtures with stabilization.

The results of the above-mentioned studies focusing on the use of pumice in geotechnical applications of road construction proved the usability of pumice as an additive in the treatment of expansive pavement subgrade, as a partial replacement material for local subbase or base material.

4. USE OF PUMICE IN FLEXIBLE PAVEMENT APPLICATIONS

Flexible pavement is a type of pavement in which bituminous mixtures are utilized to form the surface course (Naveed et al., 2022). Flexible pavements withstand severe climatic conditions throughout their service life and their performance depends on the behavior of the asphalt binder and the characteristics of the aggregate used (Kuchiishi et al., 2019). A review of the literature reveals that some studies have been performed on the use of pumice for different purposes to improve flexible pavement performance. In the following, some of them were summarized to make the issue clear.

Köfteci (2018) performed a study to investigate the usability of pumice as a mineral fibre as an alternative to cellulose fibres in stone mastic asphalt (SMA) to prevent the draining of bitumen between aggregate grains. In this context, a series of experimental analyses including Schellenberg test, wire basket test, Marshall test and water sensitivity test were performed with the fiber content of 2, 4, and 6 percent, and for control mixtures. Test results indicated that pumice in the amount of 4% could be an optimum ratio to reach satisfactory performance and as an alternative material to cellulose fibers in the SMA mixtures. In another study, Aslan and Aktaş (2018) used pumice in ratios of 1%, 1.5% and 2% as a stabilizer to prevent the drain-down characteristics of SMA mixtures. The authors reported that a minimum of 1,5% content of pumice can be used to improve the draining problem of SMA mixtures.

Hamedi and Esmaeeli (2017) studied experimentally the utilization of pumice as a fine aggregate in the production of porous asphalt (PA). In this manner, pumice was substituted with granite aggregate at levels of 2% and 5% and a comprehensive experimental analysis including indirect tensile strength, dynamic creep tests and stiffness modulus were conducted to reveal the usability of pumice as a substitution of granite. The test results as shown in Figure 5 revealed that pumice can be used to improve the characteristics of PA mixture such as resilient modulus, rutting and moisture damage. An increase in the pumice ratio caused an improvement in stiffness and a reduction in moisture damage of PA mixtures.

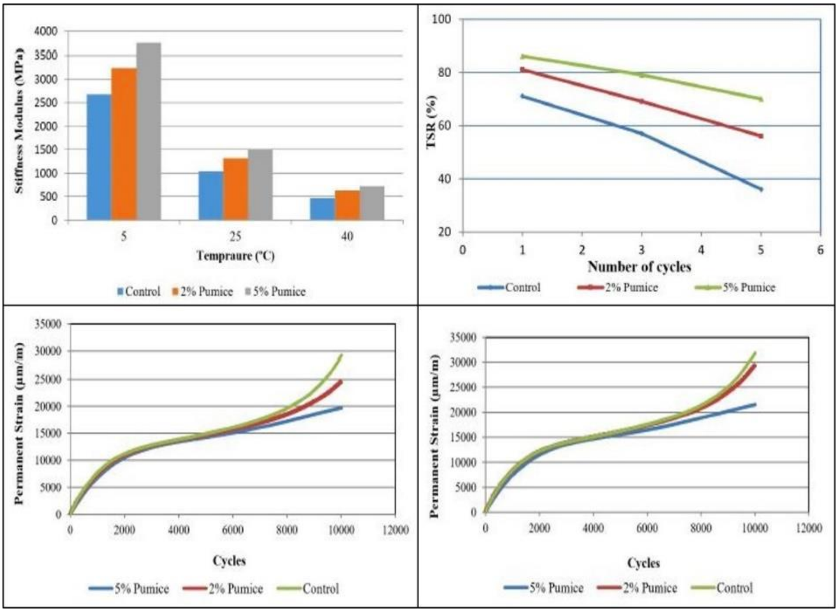

Figure 5. Effect of pumice on the properties of porous asphalt

Aslan and Bakış (2020) investigated the usability of pumice as an aggregate in the production of SMA mixtures by conducting a serial experimental analysis. Test results have shown that since pumice has a high Los Angeles fragmentation value, it can be used as a filler in SMA mixtures rather than as coarse or fine aggregate. Terzi and Büyükdoğaç (2018) performed an experimental study to reveal the usability of pumice as aggregate to produce lightweight asphalt concrete (LAC) mixtures. From the test results, the authors declared that, due to the relatively lower stability of pumice aggregate, the produced LAC mixtures can be used as a surface layer on parquet pavements and in non-heavy vehicle traffic on roads. Rizal et al. (2021) made a study to evaluate the effect of the use of pumice as a replacement material for sand on the characteristics of the surface layer of asphalt concrete mixture through Marshall stability test. The asphalt concrete mixtures were produced with different types of sand and pumice combinations including pumice 11.25%:3.75% normal sand, normal sand 11.25%:3.75% quicksand, normal sand 7.5%:7.5% quicksand and normal sand 15%:15% quicksand. The author declared from the Marshall tests that the asphalt concrete mixture with 11.25% pumice and 3.75% normal sand showed the highest stability value with 6% bitumen content. Nazary and Köfteci (2018) focused on a comparative investigation of the effect of different filler types such as limestone, zeolite and pumice on the temperature sensitivity of asphalt mastic. The temperature sensitivities of asphalt mastic mixtures were evaluated based on the softening point and penetration test results. The author reported that zeolite had relatively better high-temperature properties and limestone had better low-temperature properties.

The results of the studies performed on the use of pumice in flexible pavement applications of road construction have shown that pumice can be used as an alternative stabilizer material in SMA production and as an aggregate and filler material in asphalt concrete.

5. USE OF PUMICE IN RIGID PAVEMENTPPLICATIONS

Rigid pavement, also called concrete pavement, is a type of pavement in which cementitious mixtures are used to form the surface course (Hossiney et al., 2010). Although rigid pavements are second only to asphalt pavements in terms of current popularity (Pranav et al., 2020), they also have several specialized applications such as porous concrete pavement (Elizondo-Martinez et al., 2020), roller-compacted concrete pavement (Aghaeipour and Madhkhan, 2020), and self-compacting concrete pavement (Revilla-Cuesta et al., 2020). Portland cement and traditional aggregate are basic elements of conventional rigid pavement. However, alternative or substitute materials to cement and aggregate and mineral additives are also used to increase the strength and durability of rigid pavement (Nwakaire et al., 2020). Pumice is one of the promising alternative materials used for different purposes in rigid pavement production. In the following, some of the selected studies are summarized to make the issue clearer.

Wube (2019) searched the effect of partial replacement of grounded pumice with cement in various ratios of 5%, 10%, 15%, 20%, 25% and 30% on the performance of pervious concrete pavement (PCP) by conducting strength and permeability tests. The author declared that both compressive and splitting tensile strength of PCP were improved with 5% pumice replacement. However, the permeability of pervious concrete pavement decreased with pumice addition. In another study, Öz (2018) conducted a study to evaluate the usability of acidic pumice as a crushed natural sone substitute in PCP. The crushed stone was replaced with pumice in proportions of 10%, 20%, 30%, 40% and 50% with two different cement contents (300 and 420 kg/m^3) and comprehensive strength and durability tests were performed on different curing periods. The author stated that PCPs with pumice showed relatively better permeability and abrasion resistance regardless of the replacement level. However, with the increase in pumice substitution rate, the strength parameters decreased. The author suggested that it may be possible to use PCPs on parking areas, walkways, shoulders, slope stabilization systems, tennis courts, side streets, and roads with low traffic and low slopes.

Bakış (2018) investigated the usability of waste steel fibre reinforced reactive powder concrete (RPC) including pumice in the construction of concrete pavement. The RPC mixture was produced with pumice and the compressive strength test results were compared with that of normal-strength concrete. The author indicated that the compressive strength of RPC mixture at the end of 28 days of curing was 71.2 MPa while that of normal-strength concrete was 41.8 MPa. The author recommended the use of RPC produced with pumice in the construction of concrete pavement.

Gaus et al. (2019) studied on the usability of pumice as a fine aggregate replacement in rigid pavement production. From the test results, it was reported that the compressive strength of the normal sandy rigid pavement was almost the same as that of concrete containing pumice. It was recommended that pumice can be used as an alternative to normal sand in producing rigid pavement mixtures. Bakış (2019) performed an experimental study to investigate the usability of pumice together with lime as a cement substitute material to produce rigid pavement by performing compressive and flexural strength tests. The author reported that considering the total amount of binder, the most suitable binder ratio was determined to be 50% cement, 30% pumice powder and 20% lime in which a maximum compressive strength of 21.9 MPa was obtained as seen in Figure 6.

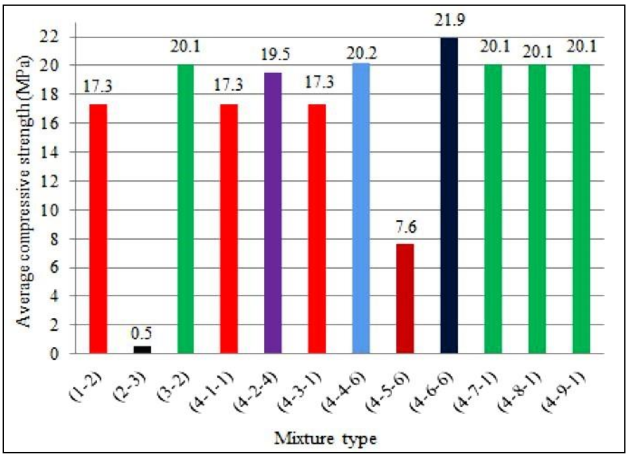

Figure 6. Change in compressive strength with different combinations of cement, pumice and lime

The review of the studies about the use of pumice in rigid pavement applications of road construction revealed the usability of pumice as a cement replacement material in ground form and as an aggregate substitute material in rigid pavement production.

6. CONCLUSION

This article presented here reviewed the usability of pumice in road construction. This was achieved by evaluating the advantages and disadvantages of pumice usage from three different perspectives including geotechnical, flexible pavement and rigid pavement. The following can be concluded from this study:

- Pumice can be used as an additive to improve the engineering properties of expansive pavement subgrade.
- Pumice can be utilized as a local aggregate substitute material to some extent to increase the bearing capacity of subbase and base layers.
- Pumice can be an alternative stabilization material to cellulose fibres in stone mastic asphalt mixtures.
- Pumice can be used as an aggregate to improve the engineering properties of porous asphalt concrete mixtures.
- Pumice, pumice can be used as aggregate in surface course for paving parking areas and non-heavy weight vehicle traffic in roads since it has relatively lower stability.
- Ground pumice can be used as a cement substitute material to form rigid pavement.
- Pumice can be used as coarse aggregate to some extent to improve the durability of pervious concrete.

7. RECOMMENDATIONS

Potential future directions for the use of pumice for different purposes in road construction are summarized as follows:

- The majority of investigations focused on the effect of pumice on the strength properties of rigid pavements. However, further research is needed to evaluate the effect of pumice on the durability characteristics of rigid pavement.

- Since pumice as aggregate has relatively low stability, the studies should focus on the usability of pumice as filler material in hot-mix asphalt mixtures.
- The most important disadvantage of rigid pavement produced with pumice aggregate is its low mechanical strength. However, this limitation can be overcome by adding fiber to concrete mixtures.
- There is a need for more studies to investigate the use of pumice in road construction, especially in terms of structural cost.

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Sustainable Transportation Systems in Civil Engineering and Managerial Informatics Assessments in Construction Systems

Depending on today's developing technology, sustainable transportation systems in Civil Engineering and management informatics in construction systems have actually become one of the key concepts of the 21st century. This concept has become indispensable, especially as the academic community has realized that conventional planning methods had negative consequences on the environment, such as pollution and the excessive use of natural resources. Naturally, professionals specializing in different engineering fields had decided to improve planning methods in order to avoid future generations from focusing on finding solutions to the problems caused by conventional planning.

To achieve a sustainable community, changes in transportation systems in Civil Engineering and management informatics in construction systems are required.

Within the scope of this book, innovative issues such as Building Sustainable Roads: Investigation Of Earth Roads On Transportation Engineering, A TOPSIS-Based Evaluation of Urban Transportation and Supermarket Accessibility: A Case Study of Konyaaltı in Antalya, Frame System Analysis with Stochastic Finite Element Method, Consultancy And Owner Representation Service In Construction Management, Building Through Crisis: The Impact Of Covid-19 On Civil Engineering Practices And Perspectives, and Using Pumice at Road Pavement Construction in Different Aspects were mentioned.

We would like to thank all the authors who contributed to the arrangement and publication of the book, especially BIDGE PUBLICATIONS.

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