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Contents

THE IMPACT OF CLIMATE CHANGE-INDUCED FLOODING ON THE RESILIENCE OF EXISTING STRUCTURES

ŞERİFE PINAR GÜVEL[1]

Introduction

The occurrence of natural disasters has been observed to result in extensive damage and significant socioeconomic losses, with an apparent trend of increasing over time (Sun et al., 2020). The comprehensive management of disasters requires the creation of awareness among the population and the conducting of large-scale risk and hazard analyses, both of which are crucial stages in the process of pre-disaster preparedness planning. Furthermore, studies have demonstrated that prompt and secure intervention is required in order to detect damages that occur both during and after the occurrence of a disaster, as well as in the context of subsequent rescue operations.

The ongoing development of new technologies in the context of disaster management continues to be a topic of ongoing research and debate in the field. In this context, early warning systems and

[1] PhD, General Directorate of State Hydraulic Works, 6th Regional Directorate, Adana, Türkiye, Orcid: 0000-0002-3175-5938

artificial intelligence represent scientific innovations that have the capacity to protect large numbers of people from the devastation caused by disasters. Furthermore, the advent of cloud storage has facilitated the rapid retrieval of information by disaster management and emergency teams. The implementation of innovative technologies, such as GPS tracking devices has become a crucial aspect of diaster mitigation and search and rescue operations. Furthermore, information systems play an essential role throughout all stages of disaster management in the assessment of risk factors. In the context of risk reduction, the utilisation of sensors, satellite imagery, and unmanned aerial vehicles facilitates real-time monitoring of the condition of natural terrain, settlements, facilities, streams, and infrastructure.

The utilisation of remote sensing (RS) enables the monitoring of alterations to the earth's surface, atmosphere and oceans, thereby facilitating the prediction of natural disasters. This facilitates the predicition and issuance of early warning of potential disasters, enabling the prompt evacuation of individuals in affected regions. In recent years, the utilisation of remote sensing techniques has enabled significant advances in the examination of a range of natural phenomena, including the investigation of earthquakes (Tronin, 2006; Matsuoka and Nojima, 2010; Zhang et al., 2024), the formation of storms (Han et al., 2017), volcanic processes (Pyle et al., 2013), as well as the analysis of flood events (Ticehurst et al., 2014; Feng et al., 2015; Revilla-Romero et al., 2015; Giustarini et al., 2015; Tanguy et al., 2017), landslides (Shafique et al., 2016), drought (Ghazaryan et al., 2020; Ghasempour et al., 2023; Zhang et al., 2023; Quirós and Fragoso-Campón, 2024; Kumar et al., 2024), and tsunamies (Jiji et al., 2019; Ghadamode et al., 2022). Furthermore, remote sensing enables the examination of changes, whether direct or indirect, that result from a variety of causes. Ontel et al. (2023) utilised satellite images in their study in land degradation and desertification mapping.

The use of geographical information systems (GIS) has become pervasive due to the advantages they offer in terms of data storage, analysis, visualisation and cost reduction, particularly in relation to the implementation process. Furthermore, GIS provides efficacious solutions to support decision-making process. Notable advancements have been made in the domain of disaster risk assessment, early warning systems, monitoring and evaluation of disaster impacts, disaster mitigation, damage assessment and mapping through the utilisation of remote sensing and GIS. Remote sensing and/or GIS have been used in several studies within the framework of disaster management (Opolot, 2013; Puttinaovarat and Horkaew, 2020; Munawar et al., 2022), disaster risk assessment (Taubenböck et al., 2011; Cankaya et al., 2016; Gelata et al., 2023; Weir et al., 2024), disaster monitoring (Yuan et al., 2019; Topçu et al., 2022; Das et al., 2023), and damage evaluation (Koshimura et al., 2020; Güvel and Akgül, 2023; Giardina et al., 2024).

Disasters can originate from many causes. Natural disasters which occur on the earth's surface, in the atmosphere and in the oceans are such events as tsunamis (Satake, 2014; Oetjen et al., 2022; Reid and Mooney, 2023), hurricanes (Van Biersel et al., 2007; Gavito et al., 2018; Qin et al., 2020; Martinez et al., 2023), storms (Ma et al., 2023), floods (Najafi et al., 2024), earthquakes (Ghamry et al., 2023), volcanic eruptions (Sari et al., 2022; Dietterich and Neal, 2022), landslides (Tanyas et al., 2019; Quesada-Román, 2021), wildfires (Nunes et al., 2019), droughts (Maybank et al., 2015), and avalanches (Campos et al., 2023).

Humans place a high value on disaster preparedness as part of their adaptation to nature and survival. In order to minimise the damage caused by disasters, many studies have been and are being carried out in different parts of the world. The role of existing buildings in reducing disaster losses after of the Great East Japan earthquake and tsunami was highlighted in the study conducted by Pushpalal and Ogata (2014).

The following methodology was employed in this study. The initial section of the study delineate the technical activities undertaken within the context of disaster management. These include pre-disaster planning and preparation, search and rescue operations during the disaster, damage assessment, and reconstruction activities following disasters. The second section will present an overview of the specific natural disasters that are the subject of this study, with a particular focus on the findings of previous studies conducted in this field. As indicated in the relevant literature, scientific studies conducted in previous years on the Ergene River floods, flood risk analysis, flood damages, and flood effects are specifically mentioned. The potential of information technologies to reinforce the resilience of the built environment in the face of floods will be examined, drawing upon the insights from the preceding sections as well as the supporting literature. The third section will present result and discussion of the research. A conclusion section will be provided, in which evaluations of the aforementioned situations will be presented.

Technical Activities Conducted within the Scope of Disaster Management: Overview

Disaster management can be broadly delineated as comprising three stages: preparation, response and recovery. A range of measures, both structural and non-structural, form part of the disaster management strategy. These measures encompass a variety of technical activities.

Some of the studies planned to be carried out in preparation for possible disaster events are as follows: The identification of current issues in the research area; investigation and analysis of historical disaster events in the designated research areas; the assessment of data acquisition methodologies; the analysis of observed data. Additionally, the identification of potential disaster scenarios and the formulation of appropriate responses in the event of their occurrence represent a crucial objective. This will entail the completion of technical, economic and other studies, including the evaluation of priorities in terms of time, the determination of criteria for the realisation of proposed solutions to problems, risk analysis, interdisciplinary coordination and the preparation of disaster plans. One of the most crucial applications of this stage is the establishment of effective disaster early warning systems, coupled with the meticulous preparation of comprehensive disaster risk maps. This process involves the determination of essential logistical considerations, such as the location, workforce, and the quantity of experts and equipment that will be required in the event of a disaster. The rapid implementation of the necessary technical measures is another crucial aspect that can significantly enhance the efficacy of this stage.

The level of success achieved in search and rescue operations during disasters is significantly influenced by the extent of preparation undertaken in advance of such events. The field of information technology has made a considerable impact on the resilience of the built environment in the context of disaster preparedness and response.

The utilisation of GIS-based dynamic risk maps provides decion-makers vital information to prevent loss of life and property, whilst also minimising the damage caused by disasters. The utility of dynamic maps in a variety of context is manifold. In addition to facilitating disaster response and monitoring the impact of crises on affected populations and infrastructure, these tools also play a crucial role in assessing the scale and scope of disasters and tracking the movements of individuals and resources in disaster-stricken areas.

Following the occurence of disasters, damage assessment strudies are conducted in the context of the built environment, along with all components of the surrounding environment that have suffered damage as a consequence of the disaster.

Previous Studies and Flood Management

The occurrence of natural disasters represents an inherent risk to human life and the environment. This is due to the intrinsic capacity of such events to inflict significant harm and pose a variety of potential dangers. The following section presents the advancements achieved through developments in information technologies, with a particular focus on the resilience of built environments in the context of disasters, through an examination of previous research.

The role of information technology in disaster management encompasses a range of activities, from the initial response to the aftermath of a disaster. This section will examine the ways in which IT can be utilised in each of these phases, outlining the potential benefits in each case.

The occurence of flood events may be attributed to a number of factors, including the rapid thawing of snow due to sudden temperature increases or the heavy precipitation that often accompanies such conditions. Over the centuries, various studies have been conducted with the objective of mitigating the adverse effects of flood events and implementing preventive measures (Angelakis et al., 2023). The role of information technologies in disaster management is manifold. These include GIS-supported flood mapping (Tehrany et al., 2015; Bui et al., 2016; Hong et al., 2018; Khosravi et al., 2019), examining flood damages using RS images (Güvel et al., 2024), analysis of impacts of flood events utilising RS, GIS and/or UAVs (Sharma et al., 2019; Rahman et al., 2021), contribution of using UAVs in search and rescue works (Hashim and Tamizi, 2018; Lyu et al., 2023), communicating with cross-city search, rescue and disaster relief teams (Shittu et al., 2018; Matsuki and Hatayama, 2023), location and route finding in flood events (Musolino et al., 2022; Suwanno et al., 2023), preparation of city information systems (Huang et al., 2022), mobile hospital, shelter, medical care, and/or food service facilities location selection (Ma et al., 2019; Tripathi et al., 2022), determining the route for nearest first aid units, real-time monitoring and dynamic damage mapping. A variety of techniques such as machine learning, image processing and data analysis, have been explored with the objective of developing effective solutions for flood management (Munawar et al., 2021).

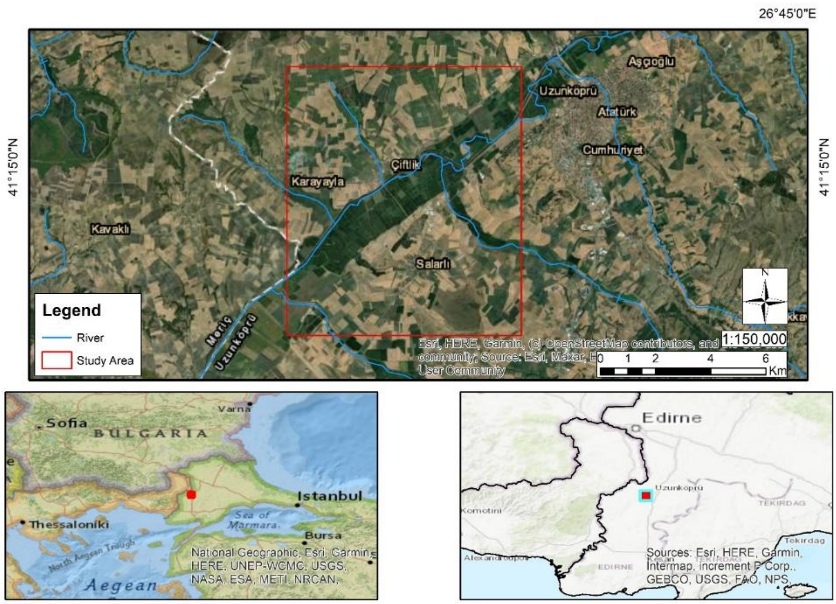
A significant number of studies were conducted over the past years to assess the direct and indirect impacts of flooding on road networks and transportation infrastructures. The following studies are a selection of those undertaken to highlight this research area; Li et al., 2019; Watson and Ahn, 2022; Haque et al., 2023.

A substantial number of technical and scientific studies have been conducted on the subject of flooding on the Ergene River in previous years. Research undertaken to date has focused on issues such as flood risks in the Ergene Basin and their effect on both agricultural areas and settlements, the damage caused by flooding, flood hazard vulnerability, flood susceptibility assessment, flooding resulting from excessively heavy rainfall, and hydrological models (Kızılaslan ve Doğan, 2013; Demirkesen, 2016; Turoğlu and Aykut, 2019; Kargı, 2019; Mesta et al., 2019; AFAD, 2021; Bayrak et al., 2021).

Study Area and Method

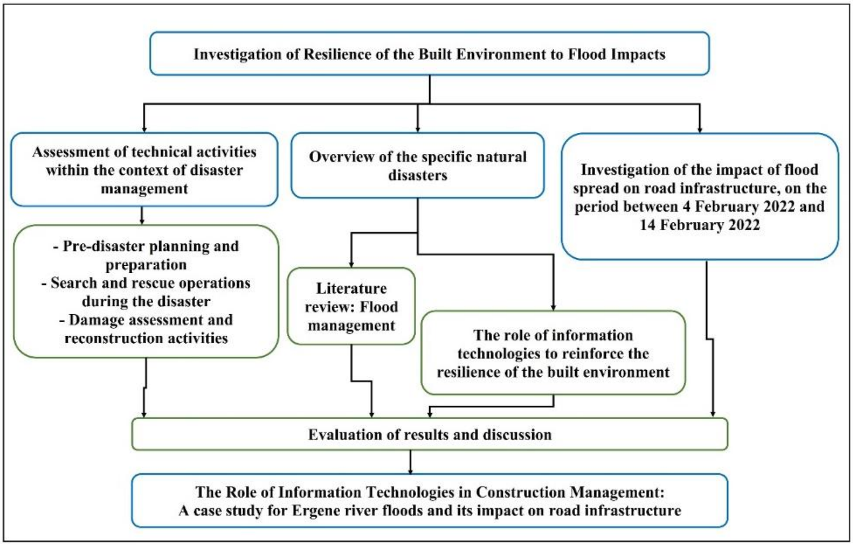
The research was carried out in the floodplain of the Ergene River within the Uzunköprü district of the Edirne Province in Türkiye. The area is located within the Meriç-Ergene Basin, which is one of the 25 basins within Türkiye. The Meriç-Ergene Basin, situated within the Marmara region, is characterised by its arable land, which renders it a suitable location for agricultural activities. Additionally, the region holds significant industrial potential. A historical analysis of flood events reveals a high incidence of flooding in the area. The specific location of this area in Türkiye can be visualised in Figure 1, which illustrates its geographical position in relation to surrounding region.

Figure 1 The location of the study area in Türkiye



This study sets out to investigate the impact of flood spreading on road infrastructure, with a particular focus on the period between 4 February 2022 and 14 February 2022. The workflow of the study is shown in Figure 2.

Figure 2 The workflow of the study



Results and Discussion

The study of the effects of floods on road infrastructure conditions represents a notable area of research. A range of methodological approaches has been used to estimate road damage from floods, with some studies focusing specifically on the flood itself or on the characteristics of the road, and some on resilience to flooding events (Sultana et al., 2016; Arrighi et al., 2021; Rebally et al., 2021; Watson and Ahn, 2022; Haque et al., 2023).

In order to examine the effect of the flood inundation in the Ergene River on the road infrastructure, four remote sensing images of the study area were examined. The results were validated with field photographs published by Anadolu Ajansı (2022). The media coverage of the flood which had occurred within the designated study area, was published in the press on 7 February 2022 (Figure 3-

b, 3-c). The title of the news was "Ergene River overflowed, causing some village roads to be closed to transportation". It was also stated that thousands of acres of agricultural land were flooded due to the river emerging from its bed (Anadolu Ajansı, 2022). As also seen in the Google Earth image of the flooded study area in the Ergene River on 6 February 2022 (Figure 3), the road infrastructure was affected by flooding.

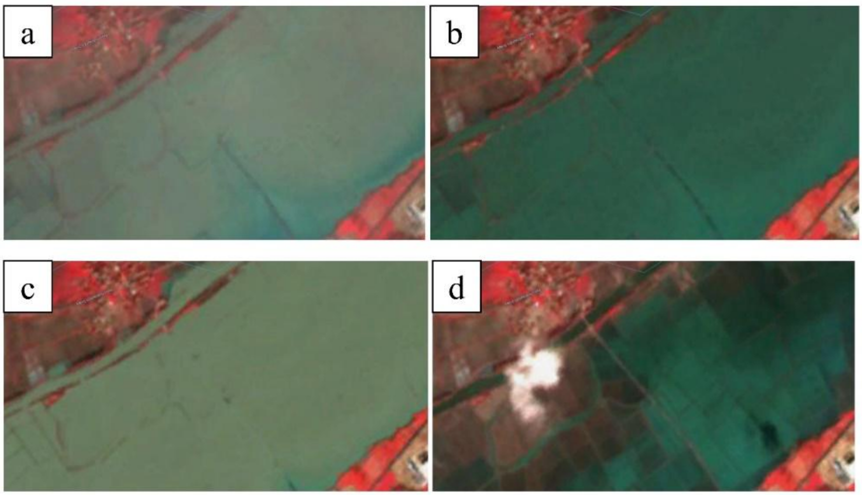
Figure 3 (a) The Google Earth image of the flooded study area in the Ergene River on 6 February 2022, (b)-(c) The image of the study area on 7 February 2022 (Anadolu Ajansı, 2022).

Figure 4 shows the condition of the bridge and the road over the Ergene River in the study area on the 16th of january, 2025, under normal conditions.

Figure 4 a)-(b) The location of transportation infrastructure in the study area in the Ergene River on 16 January 2025 (Google Earth, 2025)

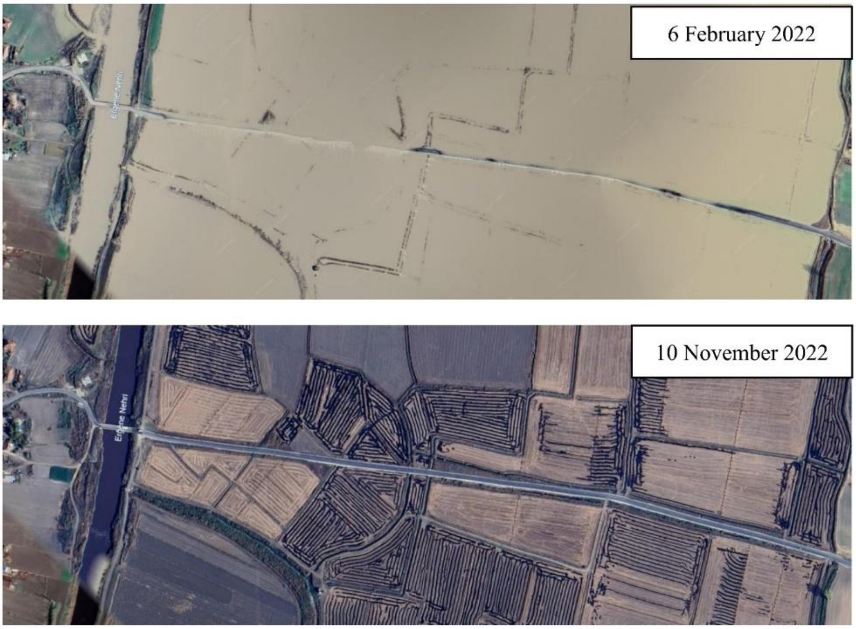
Analysis of remote sensing data has revealed the impact of floods on irrigation systems and changes in the area covered by floods. Sections were taken utilising remote sensing images and the depths of flood waters in the flood zone examined. Consequently, an evaluation was conducted to ascertain the impact of flood waters on both road infrastructure and agricultural irrigation systems. The width of the floodplain was measured from the bridge's beginning, with the sum of the bridge width and the flood spread width in the agricultural area being taken into account. Figure 5 provides a detailed overview of the alterations to the flood spread width in the river bed that occurred during the previously specified timeframe. The flood spreading phenomenon in the agricultural area and road infrastructure was examined on four dates: 4 February, 6 February, 11 February, and 14 February 2022 (Figure 5).

Figure 5 The Sentinel-2 images of the study area in the Ergene River on (a) 4 February 2022, (b) 6 February 2022, (c) 11 February 2022, (d) 14 February 2022.



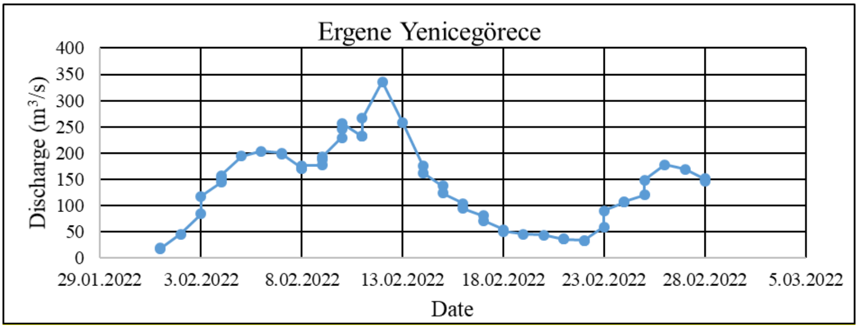
As is clearly evident in the Google Earth image dated 6 February 2022, the road infrastructure and the agricultural areas are observable as being submerged in flood waters (Figure 6). The Google Earth image of the study area in the Ergene River on 10 November 2022 is also given in Figure 6, to present the normal conditions in the study area.

Figure 6 The Google Earth image of the flooded study area in the Ergene River on 6 February 2022 and on 10 November 2022. (Google Earth, 2025)



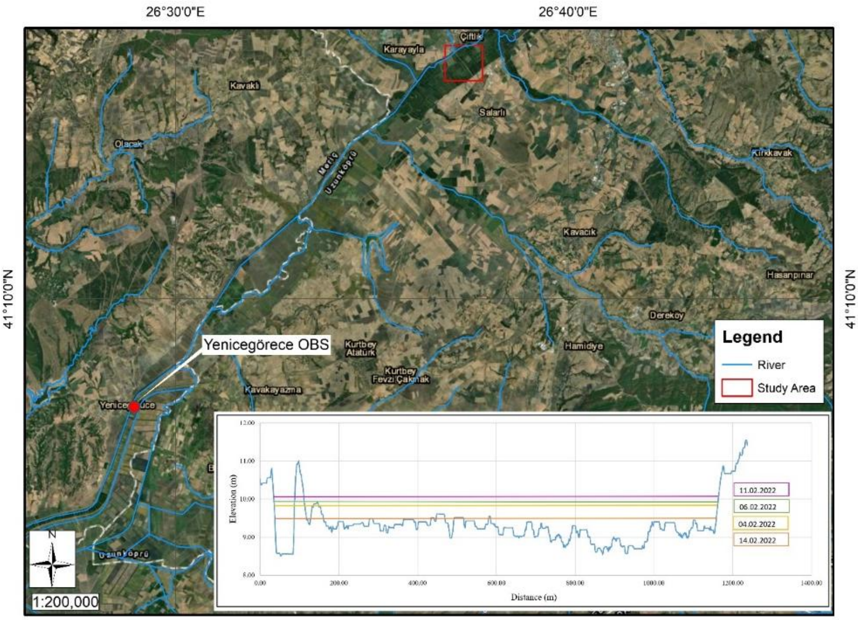
The closest flow gauging station to the study area on the Ergene river is the Ergene Yenicegörece observation station (Yenicegörece OBS). Data obtained from https://edirnenehir.dsi.gov.tr/ indicate that the flows in February 2022 were as shown in Figure 7. It was observed that the maximum flow value was recorded on 12 February, within the specified time frame of 4 February 2022 and 14 February 2022.

Figure 7 The flow observations on the Ergene Yenicegörece OBS on the Ergene River in February 2022 (https://edirnenehir.dsi.gov.tr/, access date: 20.03.2025).



As seen in the schematic drawing shown in Figure 8, a section in proximity to the designated road route, perpendicular to the flow direction of the Ergene River was selected for detailed analysis, resulting in the presentation of the longitudinal profile of this section. The discharge values recorded at the Yenicegörece OBS and the flooded area on the selected dates shown in Figure 8 were evaluated together. As a result, even after taking into account conditions such as the distance between the cross-sectional area and the Yenicegörece OBS, the involvement of stream flows, the boundaries, etc., which affect the flood spreading, the flood inundation is as shown in Figure 5. In this particular instance, the construction of the road was considerably impacted by the occurence of flooding. Recommendations for prospective endeavours aimed at enhancing the flood resilience of the built environment include the elevation of the road surface and the rehabilitation of flood control structures.

Figure 8 The schematic plan and longitudinal profiles of the designated section including the Ergene River in the study area



This study examines the role of information technologies in construction management with a particular focus on the resilience of the built environment to natural disasters in the context of flood events.

Floods are natural disasters that occur across a range of geographical regions worldwide, with a significant adverse impact on human populations, natural ecosystems, social and economic systems. For several decades, a variety of solutions, both structural and non-structural in nature, have been implemented with the objective of preventing loss of life and property, as well as reducing the harmful consequences of flood events.

The principal benefit of employing remote sensing methodologies for the delineation of flood inundation zones is the ability to gather data from locations that are either inaccessable or impractical to reach by other means.

Review of the studies in previous years on the resilience of the built environment against disasters have elucidated the advantages conferred by the utilisation of information technologies. Notable methodologies and approaches among these are GIS-supported analysis and/or models (Thrysøe et al., 2021; Shah and Shah, 2023; da Silva et al., 2023), building information modelling (Amirebrahimi et al., 2016; Yang et al., 2021), digital twins (Huang et al., 2022; Bakhtiari et al., 2023), remote sensing techniques (Jain et al., 2005; Chohan et al., 2022), which have been particularly prominent in the context of flood management.

Conclusion

The research area selected for this study was the floodplain of the Ergene River in the Uzunköprü district of Edirne province, which is located within the Northwestern Marmara region of Türkiye. The primary focus of the study was to examine the impacts of the flooding on the road that crosses the Ergene River.

The present study employed data collected from multiple sources over the period between 4 February 2022 and 14 February 2022. The investigation focused on assessing the resilience of the built environment when confronted with flood events, employing a transportation case study. The assessment involved the interpretation of remote sensing imagery and news reports obtained from multiple sources. The study’s main strength lies in the utilisation of satellite-derived images assessed through the framework of remote sensing, enabling comparisons with news photographs.

As a result of mankind’s longstanding interest and curiosity in understanding nature and living with natural hazards, disaster risk reduction and resilience continue to be important issues. Therefore, disaster resilience and sustainability of constructions in the management of the built environment is a topic interest. Societies that in ancient times fought against disasters with various primitive tools have developed many methods and precautions over the centuries. The rapid developments and advances in information technology in recent years have also brought benefits in terms of speed, labour, and cost to the technical and administrative activities carried out in this context, as well as providing support services to decision-makers.

In order to contribute to future research, this study investigated the potential of information technologies to increase the resilience of constructions to disaster events in the construction industry, specifically to flood events. The study also assessed the contribution of information technology to the durability of the built environment.

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FLOOD CONTROL MANAGEMENT WITHIN THE SCOPE OF CLIMATE CHANGE ADAPTATION

ŞERİFE PINAR GÜVEL[2]
ŞAHİN TOLGA GÜVEL[3]

Introduction

The concepts of flood risk perception and awareness have been a subject of considerable interest in the field of flood management in recent years. During the planning stages of flood control activities, field surveys are conducted to observe geographical features and environmental factors of research areas. The potential for such scenarios is assessed through the analysis of historical data, which in turn provides the framework for future projections. The implementation of various advanced techniques and tools facilitates the analysis. The assessment of precautions to be taken before flood events is generally categorised into two distinct categories: structural measures and non-structural measures.

[2] PhD, General Directorate of State Hydraulic Works, 6th Regional Directorate, Adana, Türkiye, Orcid: 0000-0002-3175-5938
[3] Assistant Prof.Dr, Osmaniye Korkut Ata University, Engineering and Natural Sciences Faculty, Civil Engineering Department, Osmaniye, Türkiye, Orcid: 0000-0002-6878-2876

Flood control infrastructure constructed as a component of structural engineering endeavours encompasses such elements as dams, enclosed channels, dikes, stone fortifications, and reclamation platforms. The implementation of non-structural measures constitues a multifaceted approach to flood risk management, encompassing the development of flood early warning systems, the dissemination of flood awareness training, and the formulation of flood plans. The execution of these studies involves the utilisation of advanced technologies, including geographic information systems and remote sensing methodologies. The coordination of multiple institutional entities, as well as the collaboration of expert teams from diverse disciplinary backgrounds, are integral components of research endeavour.

Geographic Information Systems (GIS) have been considered an effective decision support tool, with the capacity to facilitate the management process for decision makers by offering opportunities for analysis of various risks and scenarios (Aydınoğlu and Yomralıoğlu, 2003). Decision support systems (DSS) help managers with complex management problems by increasing efficiency in data management, data analysis and the development of models (Liu et al., 2009). The purpose of decision support systems is not to replace the decision-making process in the hands of managers, but to provide a framework within which informed choices can be made. The objective of these systems is to evaluate model outputs in order to produce meaningful information. Databases, numerical models and personal experiences are used to solve problems (Güvel, 2007).

The concept of a geographic information system (GIS) was first introduced in Canada during the 1960s (Turoğlu, 2000). The potential application areas of GIS are numerous and wide-ranging, including transportation and transport planning (Zeng et al., 2010; Lopes et al., 2014; Truden et al., 2022; Droj et al., 2022; Wang and

Zhang, 2024), water resources management (Tsihrintzis et al., 1996), natural resource planning and management (Nyeko, 2012; Krishna et al., 2019; Sharma et al., 2024), environmental assessments (Gharehbaghi and Scott-Young, 2018; Nowak et al., 2020), construction management (Han et al., 2020), geosciences, and, pollution control and monitoring. Consequently, it has become an important component in the practices of numerous professional disciplines and research units, including archaeology, agriculture (Sarmah et al., 2018), tourism (Amadu et al., 2025), geology (Kakavas et al., 2024), and public health (Sabde et al., 2020).

Research and analysis using GIS requires spatial data, which can be provided in different ways: collected or provided in digital form from elsewhere. GIS can analyse any subject using map elements and attribute data. Manual collection of spatial data is expensive, labour-intensive, and time-consuming, In certain instances, there is a preference for automated recording data acquisition methodologies.

GIS-based Decision Making in Water Resources Management

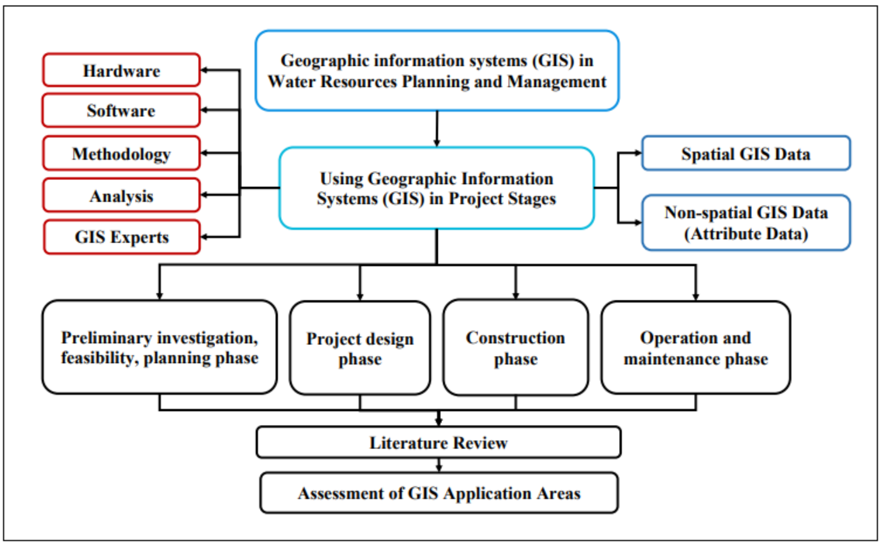
The integration of GIS technology with various data acquisition and analysis methodologies has also become increasingly prevalent, facilitating comprehensive water resources planning and management. Typically, project phases are appraised within a framework of four fundamental categories in the domain of water resources planning and development: The preliminary investigation and feasibility study represent the initial phase of the process, with subsequent planning activities forming the foundation for the subsequent stages. Following this, the design and construction of projects are initiated, and are then succeeded by the operation and maintenance. A coordinated approach, integrating the efforts of multiple professional disciplines at each stage, is fundamental.

In a GIS environment, vector data are associated with attribute information. At this step in the process, there is a higher level of labour and time intensity involved in the storage of vector data transferred from paper when associating with attribute information, when compared to those produced in digital environments such as CAD data.

The first step of this study is to present a review of previous studies conducted on the issues of water resources planning and management within the scope of each project stage. The second step focuses on flood management and presents a literature review on structural and non-structural flood measures.

A literature review of the studies conducted on the issues of water resources planning and management in previous years is presented within the scope of each project stage. The flow chart of the study is given in Figure 1.

Figure 1 The flow chart of the study



In the survey and planning stages, GIS is a tool for selecting sites and assessing their feasibility, also contributing decision making process for project managers in the analysis of geographic characteristics and environmental factors. This helps to identify constraints, assess risks and plan for environmental impacts. GIS also facilitates communication and decision-making through maps and visualisations. The utilisation of GIS data in the initial project planning stage has been shown to enable a more informed decision making process within a project management role, whilst simultaneously reducing uncertainty and optimising the site selection process. One of the most important works at this stage is terrestrial measurements and production of terrestrial maps of study areas. Moreover, it constitutes a pivotal study with regard to the generation of digital terrain models and their utilisation as a foundation for analyses.

In the initial phase of project development, there are several potential application areas that could be explored. These studies include selection of sites of observation stations, examining possibilities of implementation of upstream measures, exploration of water and land resources potential, assessment of sediment yield, environmental and meteorological conditions, drought risk, investigation of geological conditions, land use/land cover, groundwater, and economic analysis.

The utilisation of GIS has been demonstrated to yield substantial benefits within the context of river basin development and planning initiatives. This encompasses basin-specific initiatives, including the development of basin management models and the establishment of early warning systems.

In addition, GIS analyses have been employed in the evaluation of dam site selection (Njiru and Siriba, 2018; Hagos et al., 2022; Kpiebaya et al., 2025), examination of eathquake risk areas, and fault lines, and evaluation of seismic slope stability (Zhang and Wang, 2019) in several studies. Furthermore, there are studies that focus on the preparation of various thematic maps, such as the preparation of geological maps using GIS.

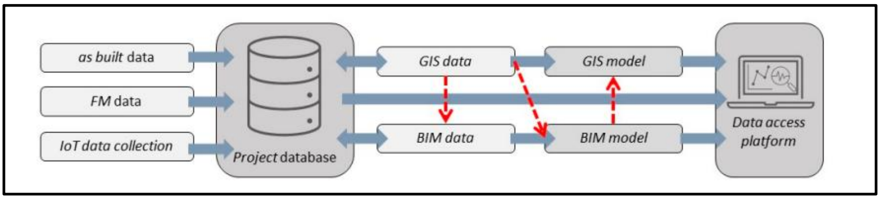
Approaches integrated with GIS enabled the identification of forest areas deemed susceptible to potential hazards such as landslides or fires, the delineation of forest roads, the analysis of the proximity of forest roads, the investigation of alterations in forest cover, and the formulation of evacuation routes in the event of forest fires, and forest management. The importance of forestry-related activities lies in their role in facilitating the integrated management of water resources and soil conservation. A substantial number of studies have been conducted on the utilisation of GIS tools in forestry (Nguyen et al., 2017; Yu et al., 2021; Cammerino et al., 2023). Evaluation of changes in land use land cover was also conducted across diverse research domains, employing remote sensing and GIS methodologies (Pande et al., 2021; Güvel, 2024).

During the project design phase, subsequent to the determination of project formulation, detailed projects are designed based on approved planning studies and subjected to review and approval processes. At this particular phase, projects that have been evaluated as being technically and economically viable are then subjected to further detailed preparation. This involves conducting supplementary field research and undertaking additional technical calculations.

In recent years, there has been an increasing trend in the utilisation of GIS and Building Information Modelling (BIM) during the design phases of various projects. BIM and GIS integration facilitate spatial analyses related to projects, thus allowing the study of spatial relationships between facilities and their constitutent elements, as well as their interatcions with the environment and/or the urban landscape. The integration of BIM and GIS within the field of construction is an area that is the focus of an increasing number of studies across the world (Zhao et al., 2019; Gilbert et al., 2021; Piras et al., 2024). The number of studies using BIM and GIS together in the construction industry is increasing, with researchers looking to explore the potential of this combined approach in various contexts (Han et. al., 2020; Zhu et al., 2021; Baarimah et al., 2022; Cepa et al., 2024; Wahba et al., 2024;).

The study conducted by Cepa et al. (2024) showed how information flows through an integrated BIM-GIS model linked to an external database in their study (Figure 2).

Figure 2 Information of flow for a BIM-GIS integration for infrastructure FM (Cepa et al., 2024)



The implementation of BIM and GIS in construction projects has been demonstrated to offer substantial advantages in terms of efficiency, particularly with regard to the management of work progress. The integration of these technologies has been shown to facilitate the execution of crucial inspections and associated technical operations, resulting in significant reductions in time and labour resources compared to conventional methodologies employed in previous years.

- Within the comprehensive framework of planning, development, and management of water and soil resources, water structure projects that are considered to be technically and economically feasible are commissioned. Achieving the expected performance of these structures is among the most important factors in operational activities. It is essential to implement a systematic approach to ensure the effective monitoring, evaluation, and operation-maintenance of projects throughout its lifecycle, thereby ensuring the expected performance is maintained.

It is an established practice to undertake systematic monitoring of hydraulic structures throughout their operational life. The regular monitoring of water resources is an integral component of broader spectrum of activities undertaken with the objective of ensuring the conservation and protection of these vital natural resources.

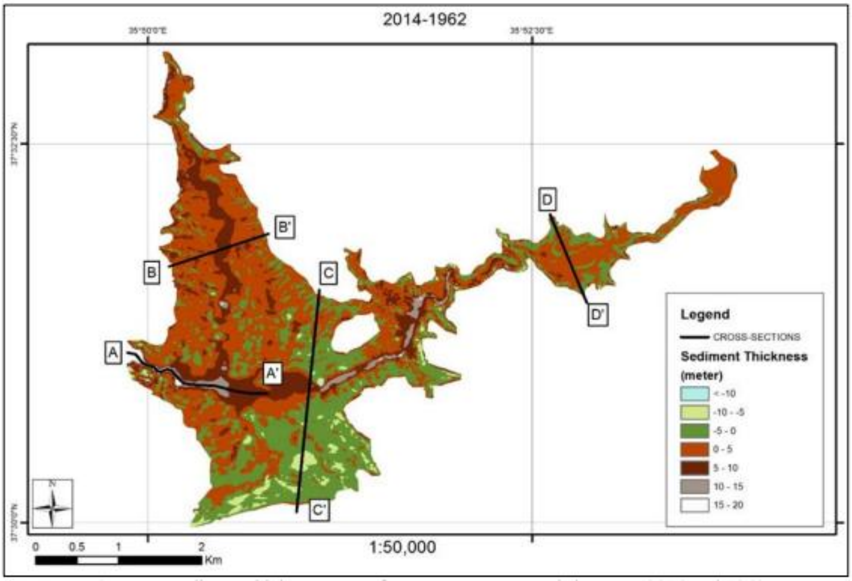
Operation and maintenance activities are intended to be executed in accordance with a sustainability approach, in response to evolving environmental and meteorological conditions, to guarantee the anticipated performance of the facilities and to maximise the economic efficiency of the facility over its entire lifespan.

Investigations into changes in underwater topography and sediment accumulation in dam reservoirs involve preparing and examining bathymetric maps. This is done to assess the impact of sediment on dam elements as part of dam reservoir operation and monitoring studies. GIS tools are used to examine temporal and spatial changes in dam reservoirs, with the objective of determining dam operation policy and implementing structural measures when necessary.

Some studies look at how changes in reservoir capacity affect operating rules; some focus on sediment removal/management. GIS is a useful tool for analysing reservoir sediments and for evaluating effects of sediment transport from upper basins across streams, as well as ascertain changes in reservoir capacity in comparison with planning data (Akgül et al., 2024).

The following illustration depicts sediment thickness maps of Kozan Dam reservoir, meticulously prepared by using GIS tools (Güvel, 2021) (Figure 3).

Figure 3 Sediment thickness map of the Kozan Dam Reservoir in GIS environment (Güvel, 2021).



In the technical activities conducted on monitoring irrigation systems during operational phases, issues covered include water quality, soil salinity, and shallow groundwater depth in irrigation networks. Water table maps in irrigation areas are prepared and assessments are made regarding measures required. GIS tools facilitate the analysis of spatial and temporal changes in irrigation systems, enabling efficient investigation of changes. Information pertaining to geographical and tabular characteristics of project components including, but not limited to, topographical features of the designated irrigation area and the configuration of irrigation channels, can be stored in the project database.

Using GIS in Flood Control Management

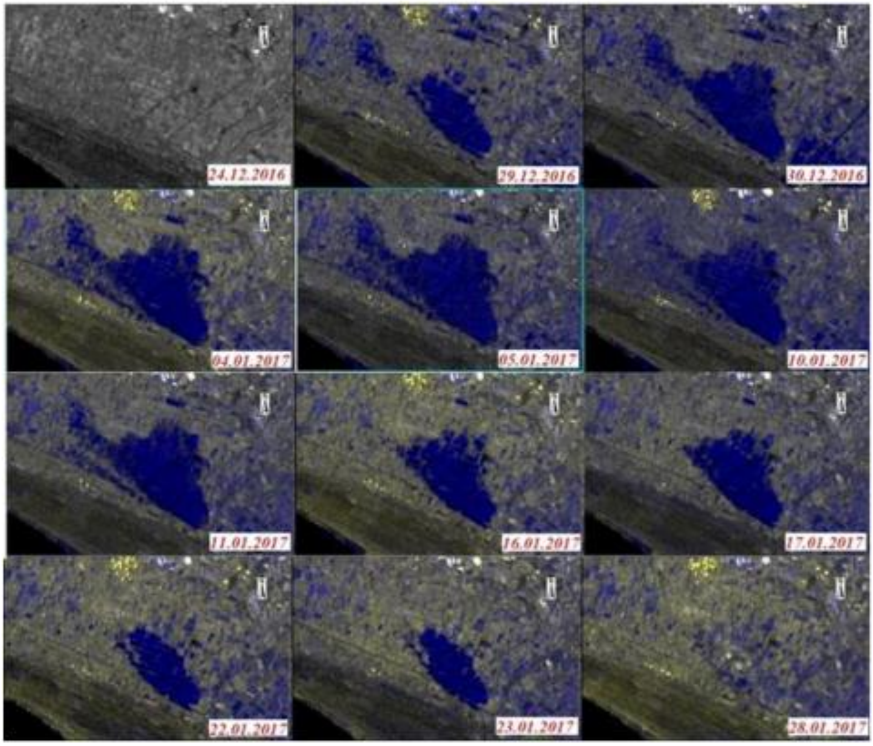
Flood risk perception and awareness are a growing focus in flood management (Baan and Klijn, 2004). Field research observation data are used in monitoring and evaluation activities of facilities, while historical data analysis is used to predict future scenarios. Flood precautions are usually divided into two categories: structural and non-structural.

Flood control facilities constructed as a part of structural activities include dams, walled channels, dikes, stone fortifications, reclamation platforms. The construction of dams is a structural measure to control the flow rates of rivers, particularly in regions characterised by a consequent elevated risk of flooding. The construction of such infrastructure has been historically driven, in large part, by the necessity of mitigating the potentially disastrous effects of flooding, particularly in rivers characterised by high flow rates. In previous years, a substantial number of studies have been conducted using GIS to implement structural measures for flood control (Patel and Dholakia, 2010; Chen et al., 2017). Non-structural measures include preparing flood risk maps, developing flood early warning systems, flood awareness training and preparing flood plans.

The issue of flood risk perception and awareness has gained increased prominence in the field of flood management (Fuchs et al., 2017). The utilisation of field research and observations has to be well-documented, as is the application of historical data analysis for the purpose of preplanning future studies. A range of sophisticated techniques and methodologies are used for analysis and assessment of findings. The integration of these advanced technologies has the potential to expedite the attainment of results, thereby facilitating significant savings in labour and costs.

A range of studies were conducted on various aspects of hydrology, including morphological characteristics (Mussina et al., 2025), precipitation/runoff, soil moisture properties, snow cover (Kumar and Kumar, 2016; Arumugam et al., 2024), evaporation losses, and climatic features. GIS was utilised in a multitude of applications in the field of water and land resources management, with a significant proportion of these applications being focused on the implementation of flood management strategies. The subjects encompass flood risk assessment (Hagemeier-Klose and Wagner, 2009), flood modeling (Kumar et al., 2023), flood hazard (Rangari et al., 2021; Santos et al., 2023; Koyuncu and Ekmekçioğlu, 2024), land use land cover changes (Güvel, 2024), soil survey and land use planning, emergency response planning (Akgül, 2024), and disaster management (Price and Vojinovic, 2008). In order to determine the extent of flooding and assess the damage incurred during such events, flood maps are prepared, and assessments are conducted so that the necessary precautions can be taken. The application of GIS tools facilitates the investigation and analysis of both spatial and temporal changes with regard to the extent of flood occurrence, as well as the monitoring of such phenomena. In the study conducted by Akgül (2018), temporal changes in flood inundated area in Berdan Plain was investigated using GIS (Figure 4).

Figure 4 Temporal changes in flood inundated area in Berdan Plain (Akgül, 2018).



Results and Recommendations

In recent years, climate change, global warming, and population growth have brought the issue on effective and sustainable management of limited water resources to the forefront. This necessisates continuous monitoring of the changing issues such as atmosphere, land structure, vegetation, environmental parameters, and the built environment, all of which interact with living organisms. Consequently, in addition to data acquisition capabilities, the ability to analyse data expeditiously, with cost and labour savings, has also gained importance. GIS techniques have been employed in numerous studies related to the management of water and soil resources, due to their rapid analysis and visualisation capabilities.

The results of this study indicated that GIS tecniques have been effectively and successfully applied in previous studies for the planning and management of water resources. The project management process may encounter specific constraints or challenges when employing GIS applications or incorporating them with other advanced technologies.

The integration of GIS with various data collection and analysis methodologies has become a pervasive phenomenon in recent years. GIS has been employed in a multitude of studies within the domain of water resources planning and management. The present study undertook a comprehensive literature review of the utilisation of GIS in the domain of water resources planning and development. The review encompasses an evaluation of project phases under four principal headings. These phases are regarded as standard practice in the construction industry and are as follows: (1) preliminary research, feasibility and planning process; (2) project design; (3) construction; and (4) operation and maintenance.

Despite the numerous examples encountered at various stages of construction projects implementation, the existing literature research indicates that GIS tools, which allow for the examination of variables affecting a wide range of areas, such as meteorological or geoscience parameters, are most preferred at the planning stage. Moreover, the integration of advanced technologies and GIS methodologies during the design, construction, and operation stages of a project has been demonstrated to yield substantial project management benefits, including considerable economic advantages in terms of cost, labour, and time savings.

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SEVERITY INDEX ANALYSIS OF CONSTRUCTION LABOR PRODUCTIVITY FACTORS IN LITERATURE DATA

ABDULKADİR BUDAK[4]
EMRE ÖZEN[5]
İBRAHİM KARATAŞ[6]

Introduction

The issue of Labor productivity in building production has been the issue of much debate for a long time and still attracts attention (Thomas & ark., 1990; Horta & ark., 2013). The most important reasons is that the Labor in construction projects is more effective than in other sectors. Regarding building production, Labor productivity dramatically affects the project's cost, quality, and duration (Albriktsen & Forsund, 1990) (Palikhe, Kim & Kim, 2019) Because, unlike other services that require Labor, almost all building production stages require physical power; therefore, a lot of Labor is

[4] Assoc. Prof. Dr, Osmaniye Korkut Ata University, Civil Engineering, Orcid: 0000-0002-6747-9103
[5] Msc. Student, Osmaniye Korkut Ata University, Civil Engineering, Orcid: 0000-0001-7799-8137
[6] Assist. Prof. Dr, Osmaniye Korkut Ata University, Civil Engineering, Orcid: 0000-0003-0845-4536

needed (Afolabi & ark., 2018). For this reason, it is essential for the construction sector stakeholders to investigate the factors affecting construction Labor productivity in the building production stages and to increase the construction Labor productivity. So, it aims to determine the factors that affect the construction Laborers' productivity and to what extent they affect it in this study. When the literature on the subject is examined, it is seen that generally, RII and rarely SI analyses are performed. However, SI analysis was not used in the reviews. Looking at the difference between RII and SI analyses, it is seen that there is a big gap in this regard. Because SI analysis covers the importance of the factors and their frequency, thus, it puts together the most important and most common factors. This will obviously help identify and solve the majority of problems. This will reflect the SI value more accurately the effect of the highly encountered factors, considering the factors affecting construction Labor productivity. Thus, the number of factors with more importance and frequency will constitute most factors affecting Labor productivity. Therefore, SI analysis was used in this study. To examine the study systematically, first of all, the studies on the subject were determined. Then, it was investigated which data collection method was obtained from the data obtained from the studies and which analysis method was analyzed. Then, using the factors obtained according to the analysis results in the studies, the weights of the factors were determined according to the RII, FR, and SI values calculated. Finally, the data obtained were considered together, and the studies carried out within the scope of the literature were examined in detail.

Material and Method

In this study, sources obtained from the literature were used. These resources were obtained from the Web of Science, Google Scholar, Scopus, and Turkey YÖK Thesis Database. In this study, using the keywords "Labor productivity", "Labor productivity," and "construction productivity," related publications, including the factors that affect construction Labor productivity in building production, were searched. The research flowchart shown in Figure 1 was followed. In this context, the studies carried out between 1983 and 2021 on the factors affecting construction labor productivity in building production, which were determined within the scope of the literature, were examined. Then, in the studies, it was determined by which method the data obtained in finding the factors affecting construction Labor productivity were obtained and which analyses were used. Then, the factors were classified under four titles, and the first 5 factors affecting construction Labor productivity the most were determined. The determined order of importance, RII (Relative Importance Index), FR (Frequency Rate), and SI (Severity Index) values were calculated as a new literature evaluation approach. When calculating the RII value, the order of importance of the factors affecting construction Labor productivity is taken as basis. According to the results of each study, the 1st factor was weighted by 5, the 2nd factor by 4, the 3rd factor by 3, the 4th factor by 2, and the 5th factor by 1 value. RII was calculated with the following Equation (Abdul Kadir & ark., 2005; Lim & Alum, 1995; Jarkas & Haupt, 2015)

$$RII = \frac{5\,n_1+4\,n_2+3\,n_3+2\,n_4+\,n_5}{5\,(n_1+n_2+n_3+n_4+n_5)} \quad (1)$$

The FR was calculated using the frequency of encountering the factors (Abdul Kadir & ark., 2005; Thomas & Sudhakumar, 2014).This study took a number of factors in the papers as the frequency value. Therefore, the FR value is considered the ratio of the number of factors in each sub-factor class affecting worker productivity, seen in each article, to the total number of factors. Thus, the FR value was calculated with the following Equation 2.

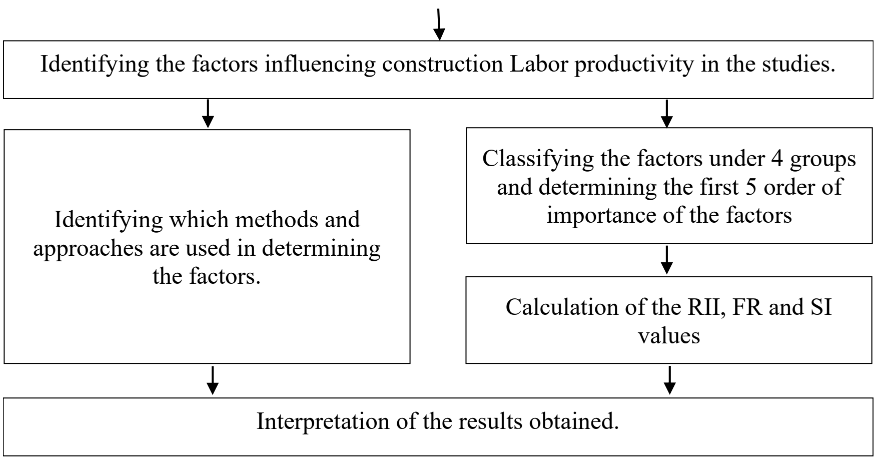
$$FR = \frac{Number\ of\ factors\ related\ the\ subfactor}{Total\ \ factors\ of\ \ in\ all\ subfactor\ class} \quad (2)$$

When calculating the SI value, it was calculated by multiplying the RII value of the factors affecting construction Labor productivity with the FR value. The SI value was calculated with Equation 3.

$$SI = RII * FR \quad (3)$$

In the studies conducted, the findings obtained with the data obtained in finding the factors affecting Labor productivity, which analyses they used, and the results of the calculated RII, FR, and SI values were analyzed by interpreting them together.

Figure 1. The flowchart to be followed in determining the factors that affect construction Labor productivity.



The Research Findings and Discussion

There are many studies on construction Labor productivity within the scope of building production in the literature. In these studies, different data collection, analysis, and evaluation methods were used. In this context, this study is analyzed in 3 phases. In phase 1, used collection methods of data; In phase 2, used analysis methods and in phase 3, the first 5 factors rank were determined. The factors that were similar and in the same category were named under a single title, and RII, FR, and SI values were calculated based on the importance order of these first five factors.

- Phase 1

Table 1 shows the data collection methods and sample sets used in studies that affect Labor productivity in building production. When Table 1 is examined, it is seen that the data collection approaches used in the studies and the selection of sample sets differ. Two data collection methods, mostly questionnaires and rarely interviews, are used in studies. A wide variety of sample sets were used as the sample set, primarily contractors, project managers, engineers, and rarely Laborers.

- Phase 2

Table 2 indicates the analysis methods used in studies that affect Labor productivity in building production. When Table 2 is examined, it is seen that the analysis methods used in the studies differ. In the studies, generally basic statistical analysis, relative importance index, rarely frequency index and severity index were used as data analysis methods. In the review studies, Severity index analysis was not used.

Table 1. Used data collection methods.

Reference	**I / Q**	**Sample Set**	**Reference**	**I / Q**	**Sample Set**
(Olomolaiye & Ogunlana, 1989)	Q	Contractors	(El-Gohary & Aziz, 2014)	Q	Consultants, Employer, Contractors
(Lim & Alum, 1995:	Q	Contractors	(Hughes & Thorpe, 2014)	Q	Project Managers
(Zakeri & ark., 1996)	Q	Site Manager	(Shashank, Sutapa & Kabindra, 2014	Q	Construction Company
(Kaming & ark., 1997)	Q	Project Managers	(Robles & ark., 2014)	Q	Contractors
(Liberda, Ruwanpura & Jergeas, 2003)	I	Industry Experts	(Odesola, Otali & Ikediashi, 2013)	Q	Contractors / Skilled Laborer / Supervisor
(Makulsawatudom, Emsley & Sinthawanarong, 2004)	Q	Project Managers	(Hickson & Ellis, 2014)	Q	Contractors
(Abdul Kadir & ark., 2005)	Q	Consultant, Contractors, Investor Company	(Jarkas, 2015)	Q	Project Managers
(Doloi, 2007)	Q	Consultant, Formen, Contractors	(Jarkas & Haupt, 2015)	Q	Contractors
(Enshassi, Mohamed & Mayer, 2007)	Q	Contractors	(Choudhry, 2015)	Q	Laborers, Supervisors and Managers

(Ailabouni, Gidado & Painting, 2010)	Q	Consultant, Contractors, Engineers	(Kazaz & Acıkara, 2015)	Q	Craft Laborers and Project Manager
(Sambasivan & Soon, 2007)	Q	Consultant and Contractors	(Gerges & ark., 2016)	Q	Project Managers, Engineers, Architectures
(Alinaitwe, 2009)	Q	Contractors	(Li & ark., 2016)	Q	Construction Laborers
(Kazaz, Manisali & Ulubeyli, 2008)	Q	Project Managers, Construction Laborers	(Thomas & Sudhakumar, 2014)	Q	Project Manager, Engineer, Laborer
(Dai, Goodrum & Maloney, 2009)	Q	Construction Laborers	(Chigara & Moyo, 2014)	Q	Consultant, Contractors
(Jang & ark., 2011)	Q	Manager, Formen, Laborers	(Hafez, 2014)	Q	Contractors, Managers, Senior Engineers
(Durdyev & Mbachu, 2018)	Q	Managers, Contractors and Subcontractor	(Tam, 2021)	Q	Project Managers, Contractors
(Ameh & Osegbo, 2011)	Q	Project Managers	(Agrawal & Halder, 2020)	Q	Construction Laborers
(Soekiman & ark., 2011)	Q	Contractors	(Golchin-Rad & Kim, 2018)	Q	Construction project managers
(Mohammed & Isah, 2012)	Q	Client, Contractors, Consultant	(Momade & Hainin, 2019)	Q	Senior engineer, Consultants, Supervisors
(Gundecha, 2013)	Q	Project Manager, Engineer, Architecture	(Alaghbari, Al-Sakkaf & Sultan, 2019)	Q	Engineers and Consultants

(Ghoddousi & Hosseini)	Q	Contractors	(Shoar & Banaitis, 2019)	I	Project manager
(Jarkas & Radosavljevic, 2013)	Q	Craftsman	(Venkatesh & Saravana, 2019)	Q	Construction Company
(Mahamid, 2013a)	Q	Contractors	(Teab & Chanvarasuth, 2019)	Q	Project manager, Site manager, engineer
(Naoum, 2016)	Q	Contract Administrators, Site Managers	(Maqsoom & ark., 2020)	Q	Construction Company
(Hiyassat, Hiyari & Sweis, 2016)	Q	Engineers, Formen	(Durdyev & Mbachu, 2018)	Q	Contractors, Project Managers
(Bekr, 2016)	Q	Employer, Consultants, Contractors	(Afolabi & ark., 2018)	Q	Contractors, Site Engineer, Project Managers
(Dixit & ark., 2017)	Q	Site Engineer, Project Managers	(Ohueri & ark., 2018)	Q	Laborer, Civil Engineer

*Questionnaires (Q) / Interviews (I)

Table 2. Used analysis methods.

Reference	Analysis Methods	Reference	Analysis Methods
(Olomolaiye & Ogunlana, 1989)	RI	(Hiyassat, Hiyari & Sweis, 2016)	Mean, Standard Deviation, RII
(Lim & Alum, 1995)	RII	(Bekr, 2016)	RII
(Zakeri & ark., 1996)	RII	(Dixit & ark., 2017)	RII
(Kaming & ark., 1997)	Rank	(Durdyev & Mbachu, 2018)	Bartlett's test of sphericity, Meyer-Olkin test
(Liberda, Ruwanpura & Jergeas, 2003)	There is no method	(Afolabi & ark., 2018)	Mean, Rank, Pearson Correlation, Analysis of Variance
(Makulsawatudom, Emsley & Sinthawanarong, 2004)	RI	(Ohueri & ark., 2018)	RII
(Abdul Kadir & ark., 2005)	RI, SI	(Golchin-Rad & Kim, 2018)	AHP and SEM
(Doloi, 2007)	Composite Factor Reliability, Average Variance, RII	(Momade & Hainin, 2019)	RII
(Enshassi, Mohamed & Mayer, 2007)	RI	(Alaghbari, Al-Sakkaf & Sultan, 2019)	RII
(Ailabouni, Gidado & Painting, 2010)	RI, FI, SI	(Palikhe, Kim & Kim, 2019)	Kaiser–meyer–olkin, Bartlett test of sphericity
(Sambasivan & Soon, 2007)	RI	(Shoar & Banaitis, 2019)	RII

(Alinaitwe, 2009)	Standard Deviation, Variance	(Venkatesh & Saravana, 2019)	Rs mean method, CII method
(Kazaz & Acıkara, 2015)	RI	(Teab & Chanvarasuth, 2019)	Skewness, Kurtosis, Index test
(Dai, Goodrum & Maloney, 2009)	RI	(Maqsoom & ark., 2020)	Range, Standard Deviation, Rank
(Jang & ark., 2011	Correlation	(Agrawal & Halder, 2020)	RII
(Durdyev & Mbachu, 2018)	Mean Rating	(Tam, 2021)	RII, Mean, Standard Deviation
(Ameh & Osegbo, 2011)	Regression, Mean, Rank	(Yi & Chan, 2013)	Critical review
(Soekiman & ark., 2011)	RII, Rank	(Naoum, 2016)	State of the Art and RII
(Mohammed & Isah, 2012)	Mean	(Hamza & ark., 2022)	Data clustering
(Gundecha, 2013)	RI, Two-tailed Test	(Choudhry, 2015)	Mean, T test
(Jarkas & Radosavljevic, 2013)	RII	(Kazaz & Acıkara, 2015)	RII
(Ghoddousi & Hosseini, 2012)	Kolmogrov Smirnov, Rank	(Gerges & ark., 2016)	RII
(Mahamid, 2013b)	RI, Group RI, Weighted Average, Standard Deviation, Variance	(Li & ark., 2016)	Mean - Range
(Mahamid, 2013a)	RI, FI, SI	(Shan & ark., 2011)	T-test
(Thomas & Sudhakumar, 2014)	RI, FI, SI, Rank	(Naoum, 2016)	RII
(Chigara & Moyo, 2014)	Mean, RII, Rank	(Robles & ark., 2014)	RII

(Hafez, 2014)	RII	(Odesola, Otali & Ikediashi, 2013)	Mann-Whitney u test, T test
(El-Gohary & Aziz, 2014)	RII	(Hickson & Ellis, 2014)	RII, Rank
(Hughes & Thorpe, 2014)	RI	(Jarkas, 2015)	RII, Rank
(Shashank, Sutapa & Kabindra, 2014)	Kmo and Bartlett's test	(Jarkas & Haupt, 2015)	RII

- Phase 3

Figure 2 indicates the distribution of articles published between 1983-2021 that the factors affect the construction Labor productivity by years. According to Figure 2, it is understood that in the last ten years, articles on the subject have intensified. Figure 3 indicates the distribution of articles published between 1983-2021 on factors affecting construction Labor productivity by continents. According to Figure 3, it is understood that articles on the subject are concentrated in the Asian continent, but very few articles are published on other continents. When the studies in the literature are examined, in some of the studies, the factors were classified (Thomas & ark., 1990; Odesola, Otali & Ikediashi, 2013; Maqsoom & ark., 2020; Tam, 2021); in some, the factors were not classified (Makulsawatudom, Emsley & Sinthawanarong, 2004; Durdyev & Mbachu, 2018; Jarkas, 2015), and in others, only certain factors were studied without classification. In this study, the basis of the study was formed based on the most essential first five factors determined as a result of each study in the literature, without considering the classifications. The most essential five factors, according to the article of each study in the literature on the subject, are summed up in Table 3. Table 3 shows that the same factors are defined under different names in different studies. For example, while (Olomolaiye & Ogunlana, 1989) and (Kaming & ark., 1997) determined a factor called "Lack of Materials" in their studies, (Enshassi, Mohamed & Mayer, 2007) and (Zakeri & ark., 1996) defined a factor called “Material Shortage”. However, it is complicated and Laborious to examine one by one in this way. Therefore, different named factors with the same meaning should be evaluated in the same category. Thus, it is clear that examining similar factors and factors that can be assessed in the same category by combining them under the same group will be more effective in obtaining a result. Therefore, by examining the first five most important factors in Table 3, factors with the same meaning and likely to be under the same group were combined under a single sub-factor class.

Figure 2. Number of articles about construction labour productivity published by year.

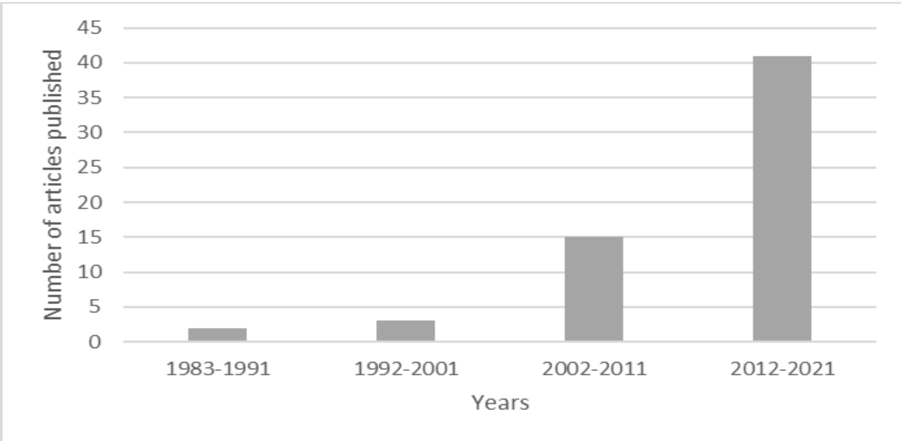
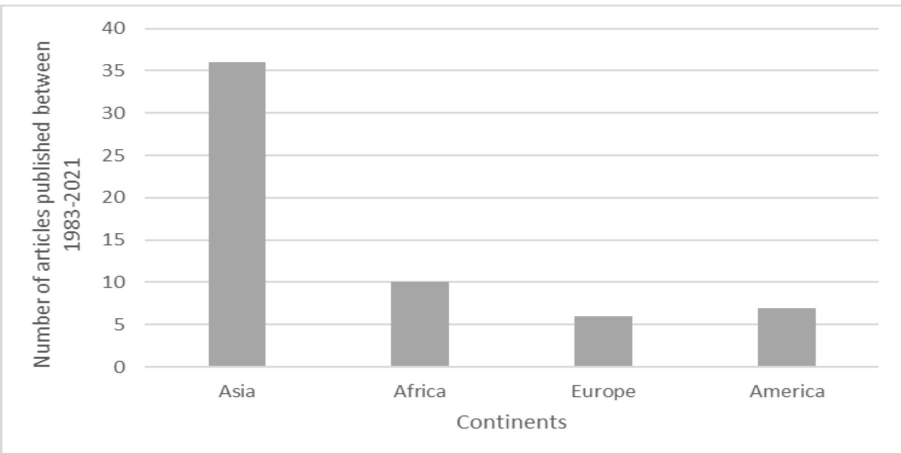


Figure 3. Distribution of articles about construction labour productivity according to continents



Classification of the factors

As seen in Table 3, the factors affecting construction Labor productivity are arranged according to the importance of the first five factors determined by the authors due to the analyses made in the studies. To effectively examine these factors, factors with the same name, those with similar names, and those in the same category should be classified within themselves. Considering the data obtained within the scope of the literature, the factors affecting construction Labor productivity were classified under different titles. In this study, the factors affecting construction Labor productivity were classified under four titles. These titles are management, technical, human, and external factors. Among the factors under these main factors, sub-factors belonging to the primary factors were formed by grouping those in the same category. Relative importance indices were determined based on the first five rows of the factors forming these sub-factor groups, and frequency ratios were determined based on the ratio of the number of sub-factors in the group to the total factor. Then, the severity indices were calculated by multiplying the relative importance indices and the frequency ratio. The weights of the factor classes were determined according to the calculated RII, FR, and SI values. Thus, factors can be interpreted with FR and SI values, not just RII values.

Table 3. The first five factors according to reference in the literature that affect construction Labor productivity.

Ref	1. factor	2. factor	3. factor	4. factor	5. factor
(Enshassi, Mohamed & Mayer, 2007)	shortage of materials	less experience	poor supervision	misunderstanding between Labor and supervision	change orders
(Abdul Kadir & ark., 2005)	shortage of materials	default payments	Ordering of changes	late instructions	Poor construction management
(Palikhe, Kim & Kim, 2019)	unavailable of tools on time at the worksite	delay in arrival of materials	procurement delay	less incentive	material payment delay
Afolabi & ark., 2018)	availability of equipment and material	supervision	Methods of construction	Welfare on site	weather condition
(Lim & Alum, 1995)	difficult in recruitment of supervisors	difficult in recruitment of workers	high rate of Labor turnover	absenteeism at the work site	communication problems with foreign workers
(Jarkas & Haupt, 2015)	error in drawings	change orders	instruction delay	poor supervisions	clarity of project specifications
(Olomolaiye & Ogunlana, 1989)	less of materials	rework	lack of equipment	supervision delays	absenteeism, and interference
(Zakeri & ark., 1996)	shortage of materials	weather and site conditions	equipment breakdown	Deficiencies of drawinqs /change orders	Less tools
(Kaming & ark., 1997)	less material	rework	absenteeism of operatives	less tools	-
(Liberda, Ruwanpura & Jergeas, 2003)	Worker experience	Worker skills	-	-	-

(Makulsawatudom, Emsley & Sinthawanarong, 2004)	less material	incomplete drawing	incomplete supervisors	lack of tools and equipment	absenteeism
(Doloi, 2007)	lack of commitment	inefficient site management	poor site condition	improper planning	Not having enough clarity scopes of project
(Ailabouni, Gidado & Painting, 2010)	proper work timings	leadership skills of supervisors	salaries on time	technical qualified	reasonably well-paying job
(Sambasivan & Soon, 2007)	Not having enough planning	financial constraints	subcontractor problems	shortage of materials	Labor supply
(Alinaitwe, 2009)	incompetent supervisor	less skills	rework	lack of tools and equipment	poor construction methods
(Kazaz, Manisali & Ulubeyli, 2008)	quality of site management	-	-	-	-
(Jang & ark., 2011)	safety accident	Manager capability	work continuity	construction plan	work method
(Durdyev & Mbachu, 2018)	poor leadership	poor planning	inadequate construction methods	poor Labor supervision	ineffective communication
(Ameh & Osegbo, 2011)	use of wrong construction method	absence of materials	inaccurate drawings specifications	inadequate tools and equipment	poor supervision of operatives
(Soekiman & ark., 2011)	less material	delay in arrival of materials	unclear instruction to Laborer	Worker protests	financial difficulties of the owner
(Mohammed & Isah, 2012)	improper planning	less communication	shortage of material	design factors	Slow decision making
(Gundecha, 2013)	lack of material	shortage power/water	accidents	less machinery	poor site conditions
(Jarkas & Radosavljevic, 2013)	Delay of payments	More rework	absent of financial incentives	change orders	Poor supervisors

(Ghoddousi & Hosseini, 2012	construction methods	site manager experience	less proper tools	inexperienced operative	Less site managers ability
(Mahamid, 2013a)	Less Labor experience	less communication and coordination between	bad relations between Labor and management team	payments delay by owner	misuse of time schedule
(Thomas & Sudhakumar, 2014)	less material	More construction parties	Absent of Drawing	less equipment	Less wages
(El-Gohary & Aziz, 2014)	less experience and skill	incentive programs	availability of the material	leadership and competency of construction management	Labor supervision Competencies
(Hughes & Thorpe, 2014	More rework	less supervisions	Less competency	incomplete of drawings	overload of works
(Shashank, Sutapa & Kabindra, 2014)	Less motivation	Not having enough manpower	Less material	Safety of construction site	Construction project management
(Robles & ark., 2014)	skills and experience's level	adapt to changes	motivation of labors	integrity	breaks number
(Odesola, Otali & Ikediashi, 2013)	craft workers' pride from works	less skills	Reworks issues	Supervisors' incompetent	issues of personal
(Hickson & Ellis, 2014)	lack of Labor supervision	unrealistic scheduling and Labor performance	shortage of experienced Labor	construction manager's lack of leadership skills	Laborers Skills
(Jarkas, 2015)	Labor skills	coordination to orders during execution	delay in responding to request for information	Less Labor supervision	Less clarity of projects' specifications
(Choudhry, 2015)	Labor skills	education experience	better communication	budget	safety
(Kazaz & Acıkara, 2015)	insurance	Payments on time	Pay amounts	conditions of dining hall and dorm	safety conditions
(Gerges & ark., 2016)	delay in material delivery on site	delays of payments	undisciplined Labor	material shortage	-
(Li & ark., 2016)	ages	Less experience	-	-	-
(Naoum, 2016)	Less experience	design errors	buildability	project planning	communication

(Hiyassat, Hiyari & Sweis, 2016)	feeling of achievement	Less experience	use of foreign workers	scheduling	use of machinery
(Bekr, 2016)	poor planning	shortage of materials	equipment shortage	shortage of labors	poor site management
(Dixit & ark., 2017)	decision making	planning	logistics	Labor availability	budget
(Ohueri & ark., 2018)	effective management and supervision	financial incentives	training and development	safe and friendly working environment	career progression
(Momade & Hainin, 2019)	achievement	proper recognition and rewards	interesting work	involvement in decision making	adequate training and development
(Alaghbari, Al-Sakkaf & Sultan, 2019)	Labor's experience and skills	availability of materials in site	leadership	availability of materials in site	political and security situation
(Shoar & Banaitis, 2019)	unrealistic schedule	excessive number of Laborers	rework	Late payment	workforce overtime
(Venkatesh & Saravana, 2019)	non-availability of clear work front	no proper planning	skill of the worker	no proper supervision	coordination between equipment
(Teab & Chanvarasuth, 2019)	project planning	labor skills	worker motivation and commitment	material supplier	rework
(Maqsoom & ark., 2020)	Experience of organizations	understanding of nature of work	supervisor' trust	competition among employees	Experience of worker
(Agrawal & Halder, 2020)	Labor personal problem	improper managerial skills	scheduling of work	high/low temperature	schedule compression
(Tam, 2021)	ability of construction management	financial status of stake holders	work discipline	rework	design changes
(Mahamid, 2013b)	political situation	equipment shortages	old and inefficient equipment	lack of Labor experience	poor site management
(Shan & ark., 2011)	effective management programs	material management & safety programs	-	-	-

(Hamza & ark., 2022)	incompetent supervisors/poor management and planning	less materials/tools/equipment	work effectiveness/experience	lack of commitment/motivation	worker efficiency/skills
(Maloney, 1983)	work intensity	duration of work	work effectiveness	worker efficiency	-
(Cooper, 2005)	overtime works	safety	realistic goals	use of technology	communication
(Durdyev & Mbachu, 2011)	rework	level of workforce skills/experience	adequacy of construction methods	buildability issues	coordination issues
(Tahir & ark., 2014)	Labor's experience and skills	incentive programs	availability of the material and ease of handling	leadership and competency of construction management	Competency of Labor supervision
(Kabiru & ark., 2017)	lack of skilled workers	material delay	weather	access to site	staff

Classification of Management Factors, RII, FR, SI and Rank values

The RII, FR, SI, and Rank values found the analysis of the factors included in the sub-factors class under the title of management factors in the literature studies are shown in Table 4. A result of the findings, according to the RII values of the management factors, it is seen that the first three factors related to work, encouragement, and planning are the most important, respectively. However, when the SI values are examined, it is seen that the first three factors, respectively, are those related to leadership and management, factors related to supervision, and factors related to planning. In this context, it is coming out that the degree of influence of the factors related to leadership, management, and supervision is high but less important in building production. The reason for this is; In building production, it can be said that the factors related to leadership, management, and supervision are given less importance, but the problems related to these factors are much more. In addition, it is coming out that the factors related to work and encouragement have a high degree of importance but have little impact on building production. When RII and SI values are evaluated together, factors related to planning are much more important than others, according to Table 4.

Classification of Human Factors, RII, FR, SI and Rank values

The RII, FR, SI, and Rank values found as a result of the analysis of the factors included in the sub-factors class under the title of human factors in literature studies are shown in Table 5. As a result of the findings, according to the RII values of the management factors, it is seen that the first three factors related to work, encouragement, and planning are the most important, respectively. However, when the SI values are examined, it is seen that the first three factors, respectively, are the factors related to Laborer skills and experiences, personal problems, education and improvement, and communication. In this context, it is understood that the factors related to the skills and experiences of the Laborer are the highest importance and the degree of influence in the production of buildings. It is seen that the degree of importance of the factors related to education and improvement is higher than the degree of influence. This is because the factors related to education and progress are more important in building production. Still, the problems associated with this factor in building production are less. On the contrary, it is seen that the degree of influence of factors related to personal problems and communication is higher than the degree of importance. This is because; It depends on the fact that the importance of personal problems and communication-related factors in building production is low according to the degree of impact, but the frequency of encountering them in building production is high. When RII and SI values are evaluated together, factors related to the skills and experiences of the Laborer are much more important than others, according to Table 5.

Classification of Technical Factors, RII, FR, SI and Rank values

The RII, FR, SI, and Rank values found as a result of the analysis of the factors included in the sub-factors class under the title of technical factors found in the literature studies are shown in Table 6. According to the RII values, the first three most influential factors are, respectively, the factors related to the rework of the faulty work, the materials and equipment, the drawing and planning. However, when the SI values are examined, it is seen that the first three factors are factors related to materials and equipment, reworking the faulty work, drawing and planning. In this context, it is understood that the factors associated with the rework of the defective work are of the highest degree, but the degree of influence in the production of the building is less. The degree of influence of the factors related to materials and equipment is higher than the degree of importance, and the degree of importance and impact of the factors related to drawing and planning is equal. The reason is that in building production, it can be said that materials and equipment are given less importance than those related to faulty construction. Still, the problems related to the factors related to materials and equipment are much more. When RII and SI values are evaluated together, factors related to materials and equipment and factors about reworking faulty works are much more important than others, according to Table 6.

Classification of External Factors, RII, FR, SI and Rank values

The RII, FR, SI and Rank values of the factors included in the sub-factors class under the title of external factors found in the literature studies are shown in Table 7. For RII values, it is seen that the first three most influential factors are, respectively, factors related to weather conditions, site conditions, political situation, refectory, and conditions of comfort. However, when the SI values are examined, the first three factors related to the site conditions, the weather conditions, the political situation, the refectory and the needs of comfort. In this context, it is understood that the factors related to weather conditions are of the highest degree. Still, the degree of impact on building production is less than the factors related to site conditions. It is seen that the degree of influence of the factors related to site conditions is higher than the degree of importance. The reason is that it can be said that in building production, less priority is given to the factors related to the site conditions, but the problems related to these factors are much more. The factors related to the political situation, the refectory, and the conditions of comfort are of equal importance and influence. When RII and SI values are evaluated together, factors related to site conditions are much more important than others, according to Table 6.

RII, FR, SI, Rank Values of All Sub-Factor Classes That Affect Construction Labor Productivity

RII, FR, SI, and Rank values found as a result of the analysis of all sub-factors in the literature studies that affect construction Labor productivity and the factors included in each sub-factor class are shown in Table 8. Considering only the sub-factor classifications of all the sub-factors found in the studies without the main factor classification, the first three sub-factors according to the Rank SI are respectively, materials and equipment, Laborer skills and experience, leadership and management. But according to the Rank RII order, the first three factors are respectively; factors related to work, Laborer skills and expertise, and reworking the faulty work. In this context, while the importance of the factors related to “materials and equipment” and leadership is relatively low in building production, it is understood that the degree of impact is high due to the many problems encountered with these factors. It is seen that the factors related to Laborer skills and experience are both important and in the second order. Therefore, it is clear that the impact of factors related to Laborer skills and experience on Labor productivity is much more significant than for other sub-factor classes. When RII and SI values are evaluated together, materials and equipment and factors about Labor skills and experiences are much more important than others, according to Table 8.

Table 4. Classification, RII, FR, SI values and Rankings of Management Factors

Sub-factors related to management factors	**RII**	**Rank RII**	**FR**	**Rank FR**	**SI**	**Rank SI**
Leadership and management related factors	0,60	5	0,17	1	10,14	**1**
Supervision related factors	0,57	7	0,15	2	8,87	**2**
Planning related factors	0,66	**3**	0,13	3	8,31	**3**
Payment related factors	0,57	7	0,13	3	7,61	4
Work related factors	0,76	**1**	0,06	5	4,79	5
Laborers related factors	0,58	6	0,07	4	4,08	6
Contract and communication related factors	0,62	4	0,06	5	3,94	7
Safety related factors	0,55	8	0,06	5	3,10	8
Encouraging related factors	0,67	**2**	0,04	7	2,82	9
Change order related factors	0,57	7	0,04	7	2,39	10
Project related factors	0,46	9	0,05	6	2,25	11
Decision-making related factors	0,55	8	0,03	8	1,55	12

Table 5. Classification, RII, FR, SI values and Rankings of Human Factors

Sub-factors related to human factors	**RII**	**Rank RII**	**FR**	**Rank FR**	**SI**	**Rank SI**
Laborer skills and experience related factors	0,75	1	0,51	1	38,11	1
Personal problem related factors	0,65	3	0,21	3	13,58	2
Education and improvement related factors	0,67	2	0,11	4	7,55	3
Communication related factor	0,44	4	0,17	2	7,55	3

Table 6. Classification, RII, FR, SI values and Rankings of Technical Factors

Sub-factors related to technical factors	**RII**	**Rank RII**	**FR**	**Rank FR**	**SI**	**Rank SI**
Materials and equipment related factors	0,65	2	0,59	1	38,46	1
Reworking a faulty work-related factor	0,68	1	0,13	4	8,72	2
Drawing and planning related factors	0,56	3	0,14	2	7,95	3
Inadequate and wrong construction methods related factors	0,51	4	0,14	2	7,18	4

Table 7. Classification, RII, FR, SI values and Rankings of External Factors

Sub-factors related to external factors	**RII**	**Rank RII**	**FR**	**Rank FR**	**SI**	**Rank SI**
Site condition related factors	0,65	2	0,59	1	38,46	1
Weather conditions related factors	0,68	1	0,13	4	8,72	2
Political situation related factors	0,56	3	0,14	2	7,95	3
Refectory and the conditions of comfort related factors	0,51	4	0,14	2	7,18	4

Table 8. RII, FR, SI values and Rankings of all sub-factors of all groups

Total sub-factors	**RII**	**Rank RII**	**FR**	**Rank FR**	**SI**	**Rank SI**
Materials and equipment related factors	0,65	6	16,08	1	10,49	1
Laborer skills and experience related factors	0,75	2	9,44	2	7,06	2
Leadership and management related factors	0,60	8	8,39	3	5,03	3
Supervision related factors	0,57	10	7,69	3	4,41	4
Planning related factors	0,66	5	6,29	5	4,13	5
Payment related factors	0,57	10	6,64	4	3,78	6
Personal problem related factors	0,65	7	3,85	6	2,52	7
Work related factors	0,76	1	3,15	7	2,38	8
Reworking a faulty work-related factor	0,68	3	3,50	7	2,38	8
Drawing and planning related factors	0,56	11	3,85	6	2,17	9
Laborers related factors	0,58	9	3,50	7	2,03	10
Contract and communication related factors	0,62	7	3,15	7	1,96	11
Inadequate and wrong construction methods related factors	0,51	14	3,85	6	1,96	11
Safety related factors	0,55	12	2,80	7	1,54	12
Encouraging related factors	0,67	4	2,10	8	1,40	13
Education and improvement related factors	0,67	4	2,10	8	1,40	13
Communication related factors	0,44	17	3,15	7	1,40	13
Change order related factors	0,57	10	2,10	8	1,19	14
Project related factors	0,46	16	2,45	8	1,12	15
Site condition related factors	0,52	13	1,75	8	0,91	16
Decision-making related factors	0,55	12	1,40	9	0,77	17
Weather conditions related factors	0,50	15	1,40	9	0,70	18
Political situation related factors	0,40	18	0,70	9	0,28	19
Refectory and the conditions of comfort related factors	0,40	18	0,70	9	0,28	19

Results

Among the total efficiency factors in building production, the Labor productivity factor can be considered the most important. Because Labor productivity is mainly based on Labor and is affected by any situation that affects labor. Labor productivity has a dynamic structure as it varies in terms of the factors it is affected by. This situation keeps the popularity of Labor productivity alive and increases the importance of related research. In this context, it aims to examine the factors affecting Labor productivity. First, a general literature review was conducted in the study. Second, it was determined by which method the data of the studies examining the factors affecting Labor productivity were collected, which sample set was applied, and which analysis method was used. Then, the factors in the determined studies were generally classified under four titles within the scope of the classifications determined in the studies. The factors belonging to each class were grouped within themselves and sub-factors were formed. Finally, the RII, FR, SI and Rank values of the factors in the sub-factors of each type were calculated based on the order of importance in the articles. A total evaluation was made within the findings obtained. During the assessment, it was observed that the RII and SI values of some factors were different. The reason is that the FR values of the factors differ according to the factor classes. For example, suppose there is only one factor in a sub-factor class. The fact that this factor is in the 1st rank in an article will be enough to move its importance to the 1st rank. However, since the FR value will be minimal, the SI value will be quite low. In this context, it is essential to consider the importance of indices and the severity indices in evaluating the main factor and sub-factor classes. So, it is clear that it would be more accurate to interpret the factors together with SI values, not just RII values. When the findings of the study are analyzed in this context, the results of the evaluation can be summed up as follows:

- Generalization has been made under four titles: management, human, technical, and external factors affecting Labor productivity. These main factor titles are divided into sub-factor classes by combining the similarities of the factors with each other and the ones in the same cluster.
- When the management main factor is examined, the first three sub-factor classes with the highest SI values are "leadership and management," "supervision," and "planning," respectively.
- When the human main factor is examined, the two sub-factor classes with the highest SI value are the factors related to "Laborer skills and experiences" and "personal problems".
- When the technical main factor is examined, the sub-factor class with the highest SI value is the factors related to "materials and equipment".
- When the external main factor is examined, the sub-factor class with the highest SI value is the factors related to "site conditions" and "weather conditions".
- The sub-factor class, which has both a high degree of importance and impact based on the main factor of management, are factors related to "planning".
- The sub-factor class, which has a high degree of importance and impact based on the human main factor, is related to the "skills and experiences of the Laborer".
- When all sub-factor classes are compared, the first 3 sub-factor classes with the highest SI value are "materials and equipment", "Laborer skills and experiences", and "leadership and management-related factors", respectively.
- When all sub-factor classes are compared, the sub-factor class, which has both a high degree of importance and

impact, is the factors related to “Laborer skills and experiences”.

- Within the scope of the results obtained, the RII, FR, SI and Rank analysis method used in evaluating this study, which is a new and different analysis of literature review, is a remarkable study in terms of setting an example for other similar studies.
- There are very few studies that examine the effects of factors related to "trust," "good morals" and "religious beliefs" under the title of personal factors. However, in many studies, the importance of these factors in construction management has been emphasized.
- There are few studies on the practical application of factors affecting Labor productivity. The practical application of these factors may have different positive implications for how to perform construction management better.

By using the findings obtained as a result of this study, the method of evaluation of the findings, and the results achieved, a new general classification for the factors affecting Labor productivity and/or new sub-factor groups can be created by adding different factors. According to the results of this study, in addition to the gaps mentioned above, studies can be diversified by using data collection methods, data analysis methods, different sample sets, and new factors that were not used in the studies. Thus, the gaps related to the subject identified in this study can be filled. In this context, it is hoped that this study will contribute to academic studies, Labor-intensive sectors, construction management, and construction production stakeholders in the private sector.

Recommendations

Examining the factors affecting Labor productivity makes it easier to understand what is known about the subject and identifies the gaps in the factors affecting Labor productivity through the order of importance of the factors and the frequency of encountering the factors. This study's gaps help identify new research first on factors affecting Labor productivity. It can be done as a continuation of this study to do new qualitative research by asking how the identified factors should be applied to the construction parties in practice. It will be crucial in the construction industry and other Labor-intensive sectors to continue the research in different geographies. This can guide other industry stakeholders in increasing productivity by showing the variation of factors affecting Labor productivity by industry. In this regard, studying how factors affect other industries is essential, and this subject could be studied in academic. By classifying the factors that impact Labor productivity most, interactions between classes can be analyzed statistically. In addition, only the most important factors or the causes of the factors with little effect and the effect of these determined causes on the factors can be investigated. This could be a potential subject of academic study in the future. Thus, considering the factors, measures can be developed against obstacles to increase Labor productivity. For parties in the construction industry, employers, contractors, designers, materials supply chain, and especially in construction management, project managers, site managers, field engineers, even foremen and regular Labors, acting on the basis of these factors are likely to help meet needs at all levels. Another critical point is that it is essential to know the factors affecting productivity, but knowing the level of impact of these factors on cost is at least as important as knowing the factors. Associating the level of impact of factors on price with the work program will be very important in maximizing efficiency. Future studies determining the cost coefficients of the factors identified in this study will fill an essential gap in the academic and private sectors.

Implications for Construction Management

In construction management, each person responsible needs to know how significant the effect of these factors is. Because these factors reflect the views and wishes of the Labors about the work through the answers given by the Labors without being under any influence, considering these factors, it is undoubted that meeting the demands of the Labors at a reasonable level will significantly increase their commitment to work and accordingly worker productivity (Osa & Amos, 2014). On the other hand, factors affecting worker productivity are a situation that should be examined under the title of leadership in construction management. Considering this situation will not only positively affect worker productivity (Jarkas & Bitar, 2012) but also increase technical personnel productivity and create integrity at all levels of management. Thus, in construction management organizations, it is hoped that considering suitable factors for each level will positively increase the success of construction management at all levels. In this context, it is vital to inform every level of construction management about the importance and implementation of the subject, to develop the companies' policies in this direction, to organize training activities on the firstic, to create awareness, and to internalize it as a culture.

Limitations

This article presents a literature review in construction management based on four databases (Web of Science, Google Scholar, Scopus, Türkiye YÖK Thesis Database). The field can be expanded in future literature reviews by adding other databases and areas examining Labor-intensive sectors. In addition, the literature review presented in this article is based on the most used terms related to Labor productivity, and different/unused new factors can be used in future studies. In addition, most of the article data sets used in the study consist of technical personnel. In other words, the results obtained are more suitable for technical personnel. Therefore, it is essential to customize novel studies by considering this academic gap in future studies.

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