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Identification and Prioritization of Rework Factors in Delays in Construction Projects Using the Hybrid Decision-Making Method of Fuzzy SWARA-WASPAS

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Abstract

Rework is one of the factors that always affects and jeopardizes the productivity of construction projects. With the increasing growth of urbanization in recent decades, provision of housing has become one of the most significant problems in Iran. The construction industry is faced with substantial problems, such as high costs of project delivery, poor financial performance, and inability to provide value to customers ahead of schedule. This paper aims to prioritize the reasons behind rework delay in terms of contractor, employer, and third party using the framework proposed in a real case study on the freeway projects in Iran. First, a number of well-known delays in freeway construction projects are considered using available theoretical resources, and then the importance of each of these criteria are identified using the stepwise weight assessment ratio analysis (SWARA) method. Based on the importance obtained by the SWARA method, the contract suspension index with the importance of 0.110 and the weather index with the importance of 0.043 are the most and least important factors in delays due to rework, respectively. Subsequently, by the importance identified, the reasons behind delays due to rework are determined using the weighted aggregated sum product assessment (WASPAS) method. According to the obtained results, the reasons for delays due to rework are prioritized. Based on the obtained results, employer ranks first, contractor ranks second, and the third party ranks third. Finally, a sensitivity analysis is carried out on the importance weights of the factors, and it can be seen that the prioritization of the causes of delays due to rework does not change with the increase in weights of the indicators.

Keywords: Prioritization, Delay, Rework, Multi-Criteria Decision-Making

Paper Type: Original Research

1. Introduction

Increase in productivity is one of the most essential issues in today's competitive world. Productivity plays a significant role in the success of any project, in particular construction projects. Today, construction projects are known as stressful and demanding projects but with low productivity. Increase in productivity can greatly affect the whole construction process, resulting into saving time, cost, and resources (Yap et al., 2020). Achieving an optimal level of productivity is effective on meeting the project goals on time and, ultimately, the success of the project. Many factors such as manpower, management team, design, communication issues, etc. affect the productivity of construction. One of the factors always affecting and endangering the productivity of construction projects is rework. With the increasing growth of urbanization in recent decades, providing housing has become one of the most important issues in Iran. In this regard, the mass production of housing has been considered as a model with advantages such as technical, economic, and time justifications, and residential complexes can be deemed as a physical manifestation of the idea of mass housing in cities. According to a report by the World Bank, a significant percentage of investments is allocated to the housing sector annually, and this sector has also managed to get a significant percentage of the GDP. Hence, productivity in residential construction is significantly important. Meanwhile, rework has an adverse effect on the performance of construction projects and ultimately decreases the profit margin, which is reflected in the cost, project time, and satisfaction of the house owners. Research conducted in this regard suggests that rework costs in poor project management can be up to 10% of total project costs. For example, according to the analyses performed, over 30% of construction works are related to rework. Rework in a

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given section results into wasting time and missing the schedule, eventually increasing costs and leading to increased complaints due to additional costs. Thus, curbing rework in the construction process is of particular importance (Yap et al., 2021). For a poorly managed project, the overall effects of rework may equal or exceed the estimated profit margin. Also, the indirect effects of rework will be seen in different aspects such as reputation, stress, motivation, and relationships. Additional time for rework, additional costs, production waste control, and additional labor for rework, and increased human supervision are direct effects of rework on project management transactions (Ye et al., 2014). The work process in construction may face suspensions. These suspensions originate from a wide range of variables such as unfavorable weather conditions, accidents at the workplace, lack of facilities such as the required equipment, machinery, and technical force by the contractor, the use of weak engineering, technical, and executive elements in the project, fluctuations in the demand for housing, rework, etc. All of the mentioned elements would disrupt the schedule by making an interruption in the work process of the project, and they would prolong the construction process by causing delays (Zhang, 2018). The construction industry is faced with significant problems including high costs of project delivery, poor financial performance, and inability to deliver value to customers ahead of schedule. Consequently, the industry has been widely criticized for poor performance and inefficient productivity. The construction industry is a tool needed to boost national economies across the world. Despite the importance of the construction industry, it has been faced with significant problems such as high costs of project delivery, unfavorable financial performance, and the inability to deliver to customers at the right time (Saidu & Shakantu, 2016). An important factor contributing to this failure is rework (Love et al, 2021). Taking into consideration the effects of rework is of great importance, and the negative performance of projects is somewhat caused by rework. Rework causes increased costs, material wastage, customer dissatisfaction, decreased quality, prolonged project completion, disagreement between contractor and customer, and as a result, it can become a legal dispute. Studies on rework indicate that the cost of rework increases up to 11% of the project cost (Satish, & Bhirud, 2018). Therefore, rework is a serious problem in the construction industry and has a negative effect on performance and productivity. Every construction project is unique and unpredictable; therefore, rework is inevitable. Usually, the principles and tools of quality management are not followed seriously in construction management, as a result, rework is accepted as an inevitable feature in the construction process. Rework is one of the major factors of wasting time and missing schedules, which ultimately affects cost, resources, and quality. Rework often manifests as overtime, the use of additional resources such as labor and factory workers, falling behind schedule, and reducing project quality. The adverse consequences of rework include reduced profits, loss of market share, damage to reputation, lower productivity, higher costs, and finally costly lawsuits between participants related to the responsibility of exceeding the set schedule and delays. Rework may occur due to lack of quality control, inadequate maintenance, use of unskilled workers and inadequate tools, etc. Rework sometimes takes place in the form of demolition and reconstruction and sometimes in the form of work needed for surplus issues. However, little is known about its background and, consequently, rework remains an inherent problem. Furthermore, since the factors leading to its occurrence are not fully known, it is difficult to find proper solutions to reduce it. Therefore, a comprehensive understanding of the mechanisms causing rework will improve the project performance. Of all the factors mentioned, this research is focused on rework, and this research aims to investigate the rework factors in order to identify and prioritize them according to their importance. Simply put, this research aims to investigate, identify, and prioritize the effects of rework scheduling on tangible performance criteria in construction projects. Therefore, the main unique contribution is as follow:

• This research provides a comprehensive analysis of the various factors contributing to rework in construction projects, offering valuable insights into the underlying causes of delays. By systematically identifying these factors, it contributes to a deeper understanding of how rework affects project timelines and budgets.

• By identifying and prioritizing rework factors, the research aids construction managers in better allocating resources. This targeted approach helps in minimizing waste and optimizing the use of time and labor, leading to more efficient project execution.

Reminder paper organized follow as, in section 2 presented literature review. In section 3 presented methodology. In section 4 presented obtained results. Finally, in section 5 presented conclusion.

2. Research Literature

Rework in construction projects refers to unnecessary activities associated with a process or activity that was not done correctly from the beginning and that activity needs to be done again (Love, 2002). Rework and waste are known non-value adding indicators affecting productivity and performance in construction projects (Alwi et al., 2002). Another definition that emphasizes the nature of rework is a work done at least one more time due to non-compliance with the requirements and to adapt to the basic requirements through completion or correction (McDonald, 2013). Al-Bataineh et al. (2012) used simulation-based analysis in the tunnel construction project for both planning and decision-making phases. Their integrated simulation was created by using a high-level architecture (HLA)-inspired communications framework. They used Simphony.NET software in their research. The method proposed by them was initially used to investigate 10 tunneling projects in North Edmonton and then used to make decisions in the execution process. Love and Sing (2013) collected information from 276 construction and engineering projects to manage and control rework risks, and analyzed the statistical characters of rework costs (direct and indirect). They found that the average total rework costs are 11.3% of the original contract figure of the project. For this purpose, they determined the empirical distribution of rework costs (direct and indirect). In this regard, goodness of fit tests were used to select the most appropriate probability distribution, and the Pareto function was generalized to select the best distribution in order to calculate the probability of rework. As a result, the initial platform was provided to check the probability of rework, and the most suitable distribution affecting the actual calculations of rework probabilities was determined. Shahin et al. (2013) followed a construction project by considering weather-sensitive activities and modeling its effects on the construction process. They showed how to model the effect of cold weather conditions on the tunnel construction project and use it in the project planning phase. Their framework is to simulate the implementation of weather-sensitive construction projects in extremely cold weather conditions. The stages of their framework include simulating and implementing the tunnel construction process under cold weather conditions and using the simulation results in the planning stage. Their simulation results clearly show the effect of cold weather conditions in the construction process and help support and decision-making and project planning. Forcada et al. (2014) investigated a highway project in Spain that had incurred a lot of rework cost and analyzed the factors that contributed to this cost, and they used them for a systematic general model that show relationships between variables. After many observations and interviews with experts and analysis of interviews and documents, they came to the conclusion that there is no significant dependence between the resulting factors, and parameters such as the risk of domain changes, high complexity and low skill levels of people cause unrealistic cost forecasts and project schedule. Alzraiee et al. (2014) introduced traditional methods such as CPM and PERT as a useful tool for construction management. Considering that in the use of the developed models, the mentioned methods do not provide realistic and correct estimation of productivity and project cost, they provided a new method that resulted from the integration of discrete event simulation and dynamic systems. Their proposed method proved to be very powerful in the analysis of construction projects. In order to test and validate their proposed model, they monitored two case studies from the construction sector. Their results show that the method proposed by them provides a better understanding of construction projects than traditional methods. After the formal description of the discrete event simulation model, Larsson et al. (2015), explained the use of the model to investigate four product and process architecture configurations for the semi-prefabricated bridge concept. This empirical evidence shows that this model can support the evaluation of the overall platform from a time perspective. The results specifically show that the discrete event simulation model based on the database can evaluate different construction methods and help managers in choosing the right options to meet the specific needs of the project. Love et al. (2019) state that this research shows that rework is a type of ambiguity that leads to the following: (1) project managers ignoring established organization-wide procedures and, at their discretion, amend them to suit their own goals while denouncing the importance of recording and learning from non-conformances; (2) a deficiency of organizational controls and routines to contain and reduce rework; and (3) an absence of an organization-project dyad that supported and promoted an environment of psychological safety. A new theoretical conceptualization of error causation that is intricately linked to rework and safety incidents is presented. The research provides managers with "uncomfortable knowledge", which is needed to provide insights into the determinants of rework that form part of their everyday practice. Love et al. (2020) conceptualized rework based on the occurrence of errors and violations in their research. The proposed reference framework provides a framework for both researchers and construction organizations to better understand the characteristics of rework causes. The consequences of gaining this understanding will be the ability to develop effective strategies to curb and reduce rework. Yap et al. (2020) appraised the correlative causes of rework and safety incidents. To do this, 20 rework causes that undermine safety performance were first identified through the literature review. Using a survey questionnaire involving Malaysian construction professionals (owners, consultants, and contractors), the causes were prioritized based on frequency, severity, and importance indices. The five leading rework-safety causes were ranked as follows: poor coordination, insufficient communication, poor subcontractor management, improper supervision and inspection, and poor site management. Spearman's rank correlation tests revealed significant agreement between the respondent groups. Yap et al. (2021) identified the causes of the initial delay of construction projects and discovered the underlying factors involved, which in practice helps to manage the construction schedule. Following a meta-analysis of 52 common causes of delay identified from the literature review, 20 highly-cited causes are categorized under client-, contractor-, consultant-, labor and equipment-, material- and others-related. A field survey was employed to acquire the views of 148 Malaysian construction practitioners from client, consultant and contractor organizations. These causes are prioritized according to an importance index that integrates both frequency and severity indices, identifying the five leading causes as lack of proper planning and scheduling, too many change orders by clients, lack of competent site management and supervision, lack of competent sub-contractors and financial problems of contractors. Spearman's rank correlation tests reveal a good consensus between the respondent groups to further corroborate the findings. A factor analysis identifies the five principal managerial capabilities influencing schedule delays to be competency management, communication and coordination management, financial management, risk management and site management.

These findings are helpful for the praxis of critical reflection in the planning and management of production in construction. This study provides the international construction community with valuable insights to reevaluate delay factors and realign project management strategies to ensure the timely delivery of projects. Love et al. (2021) stated that rework can be a problem in construction projects. While research has contributed to the accumulation of knowledge about rework, there remains limited understanding about its causal mechanisms. The result is an inability to manage and control the risks and uncertainties that surround rework causation in construction projects. This paper suggests that possessing knowledge and having an understanding of rework causation and its context is pivotal for anticipating its likely occurrence and putting in place risk mitigation strategies. Abolghasemian et al. (2021) shown the effect of reprocessing on the manufacturing process. For this purpose, the rework parameter and the variables of frequency, duration, and time of call-back have been considered. Also, the effects of these parameters on tangible performance criteria have been investigated. In this regard, we apply the combined approach of discrete-event simulation and computational modeling; then, we compare the results. Measurements show that the systems fragmented by repeated and short repetitions while referring to early are in optimal performance. Memon et al. (2023) investigated the key challenges affecting the timely completion of construction projects. The challenges were discovered from the literature and investigated to analyze their significance towards a sustainable construction project. For this purpose, observes the relationships between the key challenges using Partial Least Squares Structural Equation Modeling (PLS-SEM). A structural model was developed based on the 55 common challenges identified from literature. Data collection was administered through a structured questionnaire survey using a 5-point Likert-scale. The challenges were grouped into six constructs. The outcome reported 20 critical challenges, with information and communication-related factors being the most important challenge in the construction industry. Contract management also significantly affects project time overrun. The created model served as a starting point for academics, researchers, and practitioners to create an effective system for regulating time overrun challenges. Maelissia et al. (2023) identified the environmental factors that influence construction implementation from the contractor's perspective as the main actors in the implementation of construction. The methodology used in this research was library research and surveys using questionnaires as data instruments. The analytical method used is principal component analysis, supported by the SPSS program. Based on the analysis results of the environmental factors that influence the construction implementation level using principal component analysis, the total class produced 15 main components and was capable of explaining the various data with a cumulative percentage of 85.672%. From the study results, it can be concluded that the company resource factor was the most influential factor compared with other factors. Arantes et al. (2024) proposed combines the Interpretative Structural Modelling (ISM) and Matrix Cross Impact Matrix Multiplication (MICMAC) analyses approaches and is grounded on the opinions of construction experts collected during Focus Group Interviews (FGI). First, the critical causes of Delays in Construction Projects (DCPs) are identified. Second, the ISM model is built, representing the interrelationships between the causes and their hierarchy. Third, the MICMAC analysis is performed, revealing the strengths of the relationships among the influencing causes. Fourth, mitigation measures are developed to address the root causes identified in the previous steps, but they are designed to target and mitigate other causes, given their hierarchical relationships, driving power, and levels of dependence. Applying this methodology to the Portuguese context revealed 16 critical causes, which were then hierarchized into six levels of influence. Inadequate bidding and contract award processes and deficient communication between parties were deemed root causes, and 23 measures were put forward to mitigate DCPs. Therefore, this study contributes to the body of knowledge by designing an innovative and practitioner-wise methodology to develop mitigation measures in relation to DCPs and revealing some measures for the Portuguese context. Wepari et al. (2024) explored the effects of delays and develop strategies/framework for mitigating the effects of delay risk in building construction projects in Ghana. A cross-sectional survey research design was adopted with structured questionnaires administered to construction professionals in the building construction sector. A total of Six Hundred and Forty-four (644) questionnaires were distributed to the respondents with Three Hundred Thirty (330) questionnaires were recovered which represents a response rate of 51.2%.

Table 1. Classification of papers

Paper	Simulation		Rework		Research Methodology	
	Yes	No	Yes	No	Survey	Case study
(Ye et al., 2014)		√	√		√	
(Love et al., 2009)		√	√		√	
(Forcada et al., 2014)		√	√		√	
(Love et al., 2013)		√	√		√	
(Taggart et al., 2014)		√	√		√	
(Hwang et al., 2013)		√	√		√	
(Hwang et al., 2009)		√	√		√	
(Alzraiee et al., 2014)	√			√		√
(Shahin et al., 2013)	√			√		√
(Gonzalez et al., 2012)	√			√		√
(Lu & Olofsson,2014)	√			√		√
(Larsson et al., 2015)	√			√		√
(Nasereddin et al., 2007)	√			√		√
(Martinez, 2009)	√			√		√
(Arashpour&Arashpour, 2015)	√		√			√
(Love et al,2019)		√	√		√	
(Love et al,2020)		√	√		√	
(YAP ET AL,2020)		√	√			√
(YAP ET AL,2021)		√	√			√
(Love et al,2021)		√	√		√	
(Abolghasemian et al. 2021)	√			√		√
Maelissa et al. (2023)	√			√		√
Memon et al. (2023)	√		√			√
Arantes et al. (2024)		√	√			√
Wepari et al. (2024)		√	√		√	

3. Research Methodology

This research is a scientific work proposing a systematic framework for identifying and prioritizing rework in construction projects using multi-criteria decision-making methods. The computational part of this research depends on the use of new multi-criteria decision-making models, and the models are tested with numerical data. This research is an applied study by nature. Figure 1 demonstrates the conceptual model of the research. Based on this conceptual model, first, the most important causes of delays because of the contractor, the employer, and the third party are determined. Then, the importance (weights) of each index is determined using the weight assessment ratio analysis (SWARA) method. Considering that uncertainty is involved in the prioritization in this research, first, the process of defuzzification of the necessary data for prioritization is performed, then the final prioritization is done using the weighted aggregated sum product assessment (WASPAS) method. Finally, according to the prioritization, the necessary analysis is carried out.The assumptions of the problem are as follows:

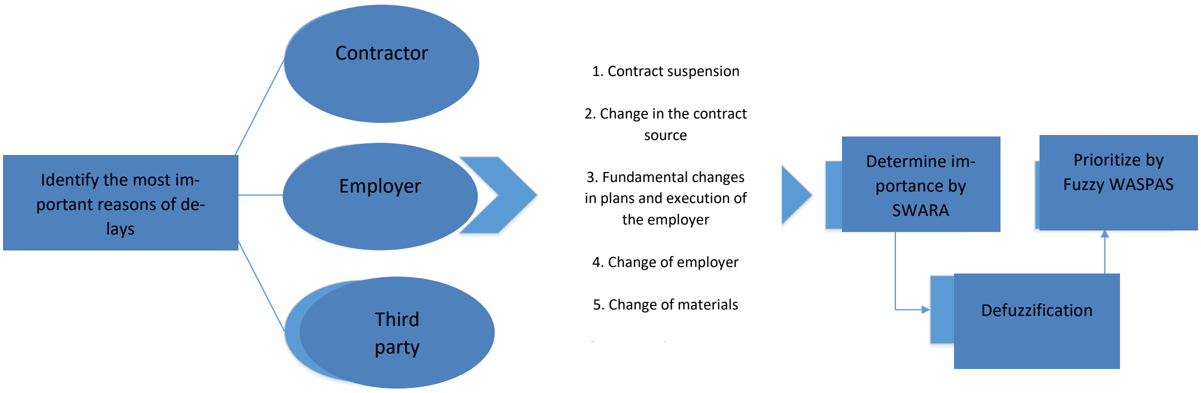

Figure 1. Conceptual model of the research

The data was collected by field and digital library studies through searching in domestic and foreign theoretical sources. During the research, the researcher undertakes to observe professional ethics regarding the confidentiality of the collected data. Also, the data collection tool in this research is viewing and searching through the digital library (SCIENCE DIRECT, IEEE, SPRINGER). The statistical population in this research are classified into two categories. The first class is the elites and experts, depending on the need to achieve opinion saturation, five elite university professors are considered. The second class includes managers working in project management as collaborators in this research. To saturate the opinion, a total of five project managers were used as participants in the second class.

4. Numerical results

In this section, we apply the framework introduced in the third section in a real case study related to freeway projects in Iran. Accordingly, considering the reviews conducted among past researches, the identified delays related to freeway projects are selected. Then, the importance of each of the delays because of the contractor, the employer, and the third party is measured so that the beneficiaries are prioritized based on the delays caused by rework.

4.1. Stages of Research

In this part of the research, we first defuzzify the fuzzy values of the observations for each reason in each index. The average fuzzy values of observations for each index are listed in Table 2.

Table 2. Fuzzy values of observations

Decision matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Contractor	(0,0,0.25)	(0.75,1,1)	(0.75,1,1)	(0.5,0.75,1)	(0,0.25,0.25)	(0,0.25,0.25)	(0.25,0.5,0.25)	(0,0,0.25)	(0,0.25,0.25)	(0,0.25,0.25)
Employer	(0,0.25,0.25)	(0.5,0.75,1)	(0,0.25,0.25)	(0.25,0.5,0.25)	(0,0.25,0.25)	(0,0.25,0.25)	(0,0,0.25)	(0.75,1,1)	(0,0.25,0.25)	(0.5,0.75,1)
Third party	(0,0,0.25)	(0.25,0.5,0.25)	(0,0.25,0.25)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0,0,0.25)

According to the data collected for each index for each reason, according to the defined spectrum, the certain values of the observations are used for calculations and analysis of the results regarding the determination of importance and prioritization.

4.2. Determining the importance of factors affecting delays of rework

In this part of the research, the importance of each of the 10 identified factors is calculated based on the SWARA method. Fuzzy values are used so as to make the results closer to the real world. The resulting decision matrix from experts' point of view for implementing the SWARA algorithm is shown in Table 3. This matrix is formed based on the relative average of the opinions of 10 experts participating in this research after defuzzifying the results listed in Table 2 according to the defined spectrum.

Table 3. The decision matrix of the problem

Decision matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Contractor	0.063	1.063	1.063	0.875	0.313	0.313	0.625	0.063	0.313	0.313
Employer	0.313	0.875	0.313	0.625	0.313	0.313	0.063	1.063	0.313	0.875
Third party	0.063	0.625	0.313	0.875	0.875	0.875	1.063	0.875	0.875	0.063

The unscaled matrix is determined according to the SWARA method using Table 3.

Table 4. The unscaled matrix

Unscaled matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Contractor	0.013	0.134	0.163	0.122	0.048	0.054	0.123	0.014	0.054	0.052
Employer	0.065	0.11	0.048	0.087	0.048	0.054	0.012	0.236	0.054	0.144
Third party	0.013	0.079	0.048	0.122	0.135	0.152	0.21	0.194	0.152	0.01

By completing Tables 3 and 4, according to the relationships in the SWARA method, we consider the value of λ_j equal to 0.111 for each index. Then, we consider the value of k_j equal to 1 for C_1 and equal to $1 + \lambda_j$, that is, 1.111, for other indices. By applying the assumptions considered for the fuzzy SWARA method, the initial weight is calculated according to Table 5.

Table 5. The initial weight of the indices in the fuzzy method

Index	Initial weight
C1	1
C2	0.90
C3	0.81
C4	0.73
C5	0.66
C6	0.59
C7	0.53
C8	0.47
C9	0.43
C10	0.38

Finally, the final weight of the indices is calculated according to the fuzzy method in Table 6.

Table 6. Final weights of the indices in the fuzzy SWARA method

Index	Initial weight
C1	0.110
C2	0.099
C3	0.089
C4	0.080
C5	0.072
C6	0.065
C7	0.058
C8	0.052
C9	0.047
C10	0.043

Figure 2 displays the chart for the importance of each criterion affecting the occurrence of delays of rework.

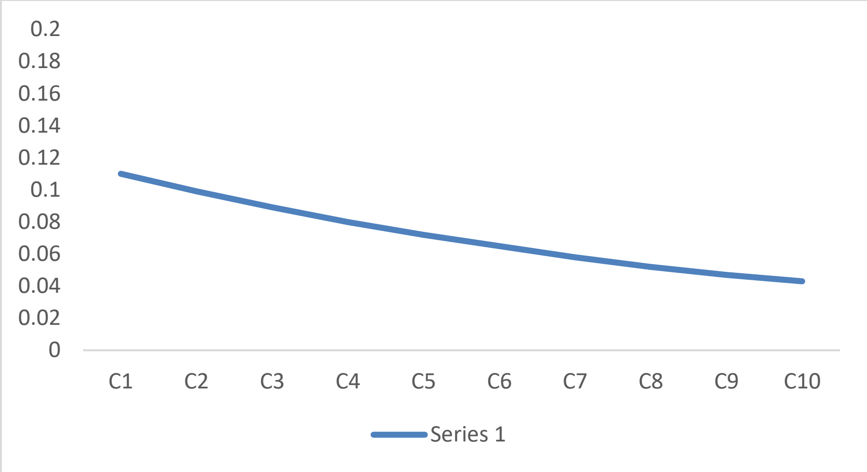

Figure 2. Importance of the research's criteria

Based on the importance obtained according to the SWARA method, the contract suspension index with the importance of 0.110 is the most important and the weather index with the importance of 0.043 is the least important in the occurrence of delays due to rework. Other factors are important as illustrated in Figure 2. Therefore, the contract suspension index would have the greatest effect on the occurrence of delays from the contractor, employer, and third party. At this stage, the degree of effectiveness of each factor is determined. In the following, by prioritizing, we determine which of the beneficiaries participating in the project cause more delays due to rework.

4.3. Prioritizing the causes of rework

In this part of the research, we prioritize the causes of rework in terms of the employer, contractor, and third party as the project beneficiaries. For this purpose, the WASPAS method was used based on the collected decision matrix. Table 7 shows the scaled decision matrix of the WASPAS method. It should be noted that due to the fact that the indices are related to rework, they are considered negative.

Table 7. The scaled decision matrix of the WASPAS method

Decision matrix	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Contractor	0.063	1.063	1.063	0.875	0.313	0.313	0.625	0.063	0.313	0.313
Employer	0.313	0.875	0.313	0.625	0.313	0.313	0.063	1.063	0.313	0.875
Third party	0.063	0.625	0.313	0.875	0.875	0.875	1.063	0.875	0.875	0.063
Min value	0.063	0.625	0.313	0.625	0.313	0.313	0.063	0.063	0.313	0.063
Normalized matrix										
Contractor	1	0.587	0.294	0.714	1	1	0.101	1	1	0.201
Employer	0.201	0.714	1	1	1	1	1	0.059	1	0.072
Third party	1	1	1	0.714	0.357	0.357	0.059	0.072	0.357	1
w_j	0.11	0.099	0.089	0.08	0.072	0.065	0.058	0.052	0.047	0.043

According to the unscaled values and the weights obtained from the SWARA method, the Q_1, Q_2, and Q values of the WASPAS method are calculated as described in Table 8.

Table 8. Values of the WASPAS indices

Cause of delays of rework	Q_1	Q_2	Q	Rank
Contractor	0.502058	1.0244E-07	0.251029	2nd
Employer	0.510033	2.1091E-08	0.255016	1st
Third party	0.471144	7.8672E-09	0.235572	3rd

According to the obtained results, the prioritization of the reasons behind delays of rework is determined. Based on the obtained results, the employer ranks first, the contractor ranks second, and the third party ranks third. Therefore, it is clear that the delays caused by employers' rework in construction are more than other cases.

4.4. Sensitivity analysis

In this part of the research, a sensitivity analysis is carried out on the parameter affecting the problem solving. For this purpose, the weights obtained by the SWARA method are changed. To do this, the weights are increased by 0.1. The goal is to find out how the prioritization of the reasons behind delays in rework would change, if the weights change. Table 9 shows the result of changes in the scores of the WASPAS method in exchange for an increase of 0.1 in the weights of the effective factors.

Table 9. Changes in the WASPAS scores in exchange for increasing weights

Cause of delays of rework	Q_1	Q_2	Q	Rank
Contractor	1.191935	6.88416E-06	0.595971	2nd
Employer	1.214716	1.43884E-06	0.607359	1st
Third party	1.063013	5.12943E-07	0.531507	3rd

According to Table 9, if the importance of factors increases, the scores of WASPAS would increase as well, but it would not cause a problem in the prioritization of factors.

4.5. Managerial insights

Managerial Insights for Identifying and Prioritizing Rework Factors in Delays in Construction Projects are followed as:

1. Proactive Risk Management: Managers should establish a proactive risk management framework to identify potential rework factors early in the project lifecycle. Regular risk assessments can help anticipate issues that may lead to delays and additional costs.

2. Effective Communication: Enhancing communication among all stakeholders, including contractors, subcontractors, and suppliers, is crucial. Clear channels of communication can help in quickly identifying problems and reducing misunderstandings that lead to rework.

3. Training and Development: Investing in training programs for workers and project managers can significantly reduce rework. Ensuring that all team members are well-versed in construction standards, quality control measures, and project specifications can minimize errors.

4. Standardization of Processes: Implementing standardized processes and best practices across projects can help in reducing variability. This consistency can lead to fewer mistakes and a reduction in the need for rework.

5. Utilization of Technology: Leveraging construction management software and tools for project tracking, documentation, and communication can enhance efficiency. Technologies such as Building Information Modeling (BIM) can help visualize projects and reduce errors before construction begins.

6. Prioritization of Rework Factors: Establish a systematic approach to prioritize rework factors based on their impact on project delays and costs. This prioritization should guide decision-making and resource allocation to address the most critical issues first.

7. Feedback Mechanisms: Develop feedback loops that allow teams to learn from past projects. Analyzing previous rework instances and their causes can provide valuable insights for future projects and help in refining processes.

8. Collaboration and Teamwork: Fostering a culture of collaboration among project teams can enhance problem-solving capabilities. Encouraging teamwork can lead to innovative solutions that minimize rework and streamline project execution.

9. Performance Metrics: Implementing key performance indicators (KPIs) related to rework and delays can help monitor progress and identify areas for improvement. Regularly reviewing these metrics can provide insights into the effectiveness of current strategies.

10. Continuous Improvement: Emphasize a culture of continuous improvement within the organization. Regularly revisiting and updating processes based on lessons learned from rework incidents can drive long-term improvements in project performance.

By focusing on these insights, construction managers can effectively address rework factors, mitigate delays, and enhance the overall efficiency of construction projects.

5. Conclusion

Achieving an optimal level of productivity affects meeting the project goals on time and ultimately the success of the project. Many factors such as manpower, management team, design, communication issues, etc. affect construction productivity. One of the factors that always affects and endangers the productivity of construction projects is rework. With the increasing growth of urbanization in recent decades, providing housing has become one of the most substantial issues in the country. The construction industry is faced with significant problems including high costs of project delivery, poor financial performance, and inability to deliver value to customers ahead of schedule. Consequently, the industry has been widely criticized for poor performance and inefficient productivity. The construction industry is a tool needed to boost national economies across the world. Despite the importance of the construction industry, it has been faced with significant problems such as high costs of project delivery, unfavorable financial performance, and the inability to deliver to customers at the right time. An important factor contributing to this failure is rework. Taking into consideration the effects of rework is of great importance, and the negative performance of projects is somewhat caused by rework. Rework causes increased costs, material wastage, customer dissatisfaction, decreased quality, prolonged project completion, disagreement between contractor and customer, and as a result, it can become a legal dispute. This paper aimed to prioritize the reasons behind rework delay in terms of contractor, employer, and third party using the framework proposed in a real case study on the freeway projects in Iran. First, a number of well-known delays in freeway construction projects were considered using available theoretical resources, and then the importance of each of these criteria were identified using the SWARA method. Based on the importance obtained by the SWARA method, the contract suspension index with the importance of 0.110 and the weather index with the importance of 0.043 were the most and least important factors in delays due to rework, respectively. Subsequently, by the importance identified, the reasons behind delays due to rework were determined using the WASPAS method. According to the obtained results, the reasons for delays due to rework are prioritized. Based on the obtained results, employer ranked first, contractor ranked second, and the third party ranked third. Finally, a sensitivity analysis is carried out on the importance weights of the factors, and it can be seen that the prioritization of the causes of delays due to rework did not change with the increase in weights of the indices. In this research, using multi-criteria decision-making methods, the importance of factors affecting delays caused by rework were weighted, and then the causes of delays were prioritized. By using the literature study in the available theoretical sources, the most important factors affecting delays in rework were identified according to Table 10.

Table 10. Indices affecting delays caused by rework

Factor	Reference	Symbol
Contract suspension	Arashpour et al. (2022)	C_1
Change in the contract source	Wang et al. (2018); Yap et al. (2021)	C_2
Fundamental changes in plans and execution of the employer	Yap et al. (2020); Yap et al. (2021)	C_3
Change of employer	Satish et al. (2018)	C_4
Change of materials	Abolghasemian et al. (2021); Yap et al. (2021)	C_5
Force majeure events	Abolghasemian et al. (2021); Yap et al. (2021); Arashpour et al. (2022)	C_6
New rules	Zhang et al. (2018)	C_7
Antique discovery	Love et al. (2021)	C_8
Financial obligations	Larsson et al. (2015); Satish et al. (2018)	C_9
Weather	Arashpour et al. (2022)	C_{10}

The importance of each of these criteria were identified using the SWARA method. Based on the importance obtained by the SWARA method, the contract suspension index with the importance of 0.110 and the weather index with the importance of 0.043 were the most and least important factors in delays due to rework, respectively. Subsequently, by the importance identified, the reasons behind delays due to rework were determined using the WASPAS method. According to the obtained results, the reasons for delays due to rework are prioritized. Based on the obtained results, employer ranked first, contractor ranked second, and the third party ranked third. The most important suggestion for recommendations of the research are: Using other prioritization methods such as VIKOR, TOPSIS, ELECTRE, etc. and comparing the results obtained with this research. Using integrated techniques such as Copeland and Borda to create a single prioritization based on different prioritizations created from various methods. Using other weighting methods such as Shannon's entropy and the best-worst method. Using integrated weights.

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