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# Identification Risks in Road Construction Projects Using Weighted Product Model: Iraq as a Case Study

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## ABSTRACT

One of the challenges that developing countries is the necessity to properly manage the risks involved in road construction projects. For that, the present work developed a dissension method to specify effective risk factors in a wide range of approaches and protocols to achieve its objectives. The Influence of Risk Road Implementation on Performance Indicators The initial sets of outcomes were derived from computing the average risk estimate. Subsequently, the second results group was established by assessing the relative importance index (RII) effects. In the RII method and mean results the workers and machinery insurance is the most important. The identical data that had been collected from the weighted product model (WPM) methodology ultimately determined that the essential resources such as staff and equipment must be accessible through all stages of activity. In road construction, machines represent a major effective factor that can help to project success with a rank of 0.868. Also, the worker conditions and skills represent another strategy in projects with 0.547 rank. The weighted product model results yelled a more accurate and practical output.

**Keywords:** Weighted product model, Risks of road construction project, Relative importance index

## 1. INTRODUCTION

Road construction projects pose numerous hazards that may lead to higher administrative project expenses for the contractor. The risks involved include escalating labor costs, inflation-driven material price hikes, and potential delays in project completion. Nevertheless, the construction process is vulnerable to a wide array of deviations and unforeseen circumstances that arise from various sources. While the timely completion of projects is a sign of efficiency, it can still be influenced by other factors. Risks commonly occur during road construction projects, even though their timely completion is crucial for their success **(Rashid, 2023)**. An advantage of undertaking a thorough study of risk factors is the capacity to mitigate adverse impacts on project performance. Although considerable

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research has been devoted to the examination of construction risks, there is a scarcity of studies that have specifically examined construction risks in nations with similar levels of competitiveness **(Marwa et al., 2022)**.

Kong and Koor, in 2020 examined the process of mitigating geotechnical hazards. This was achieved by implementing mechanisms that guaranteed the presence of qualified workers on-site and promoted effective communication among site staff, the design team, and the contractor. The iterative improvement of the conceptual essential model throughout the project was a crucial tool for managing risks **(Kong et al., 2020)**. Da'as in 2008 conducted an empirical study on a risk assessment module specifically developed for public road construction projects. This dissertation analyzes a case study of a road construction project aimed at creating a new route to a tertiary institution located on the East Coast of Malaysia. The specified pair-wise questionnaire survey was distributed to the road project team using the Analytic Hierarchy Process (AHP) approach. To assess the risk of construction delays, it was imperative to prioritize the relevant elements based on their importance and conduct a sensitivity analysis to determine the most crucial phase **(Da'as, 2008)**. An investigation was undertaken by Rashid in 2016 to identify the primary contributors to budget and schedule overruns in Pakistani highway construction projects with twenty-one consultants, and twenty-five contractors **(Rashid et al., 2016)**. Another study proposed a total of thirty-two factors that cause delays and twenty-eight elements that cause cost overruns were evaluated using the relative relevance index **(Chandubhai et al., 2019)**.

Mike Black in 2017 presents a comprehensive examination of the geological history of the scheme and emphasizes the initial specification of substantial geotechnical hazards. Furthermore, it clarifies how extensive desk research, meticulous field investigations, and significant interpretive reporting conducted by clients all contributed to a more precise evaluation of the particular risks posed by these hazards **(Black, 2017)**. The geological conditions and associated geotechnical challenges have been found to substantially impact the financial and temporal aspects of large-scale civil engineering endeavors, according to research **(Hoek et al., 1998)**. The cost impact index (CII), schedule impact index (SII), and frequency index (FI) of geotechnical concerns indices were subsequently applied to assess the importance of every risk. In Turkey, 47 professionals employed in the heavy civil construction sector participated in a survey **(Koc et al., 2020)**. Dishar in 2022 proposed the utilization of the risk score technique as a means to ascertain the qualitative risk analysis criteria in the tendering phase of construction projects. To evaluate potential hazards, the authors of this article organized a panel of specialists and administered a questionnaire to measure the probability and consequences **(Dishar et al., 2022)**.In 2023, Jalhoom proposed an evaluation of the potential impacts of hazards on the aims and security of construction projects in Iraq. This study utilizes prior research to demonstrate that risk cost is a widely acknowledged measure for assessing risk. The metric is commonly denoted as a proportion of the project's initial expenditure and is universally comprehended by all stakeholders engaged in the construction procedure. The proposed method simplifies the utilization of risk cost in risk assessment, hence facilitating practical experience. It possesses the capacity to enhance risk evaluation in practical settings and attract professionals from the building industry. There exists a present disparity between the theoretical and practical aspects of assessing building risks. This work is a component of a broader research endeavor that seeks to reconsider the modeling and evaluation of construction risks **(Jalhoom et al., 2023)**.

The study conducted by Rasheed in 2015 proposed two key dimensions of efficient risk management. Firstly, it explored the importance of different levels of analysis and risk management to specific strategies. Secondly, it emphasized the necessity of proactive measures in addressing risks to ensure their effective management in construction projects. Through an analysis of various construction projects and academic literature, along with extensive interviews with professionals in the construction industry, this study identifies several real-life risks and evaluates their potential consequences on the project's objectives and safety **(Rasheed et al., 2015)**.

Mohammed in 2014 conducted a study on the safety construction management plan. The research studied the highest grades while assessing safety parameters. While this particular case study does not pertain to Iraqi projects, our overarching objective is to enhance the overall quality of work in Iraq. After watching the administrative work style and severity ratings assigned to each phase of the work, an understanding of the most perilous circumstances in multi-story building projects was developed. Researchers gathered evaluations for 46 events and the corresponding types of risks assessed in each to identify different risk mitigation measures. Subsequently, a survey format was disseminated to prominent specialist institutions and organizations in Iraq and the United Arab Emirates. Ultimately, the researcher uses the data to develop software that can be easily downloaded on any individual's computer. This software enables users to analyze prospective hazards, devise strategies to mitigate them and determine appropriate actions to take in the case of their occurrence **(Mohammed et al., 2014)**.

The present research aims to specify the most crucial component to discover and improve the already utilized methodologies for model building and analysis. Regarding these hazards, the challenge is whether existing methods are adequate for building roads with potential for harm. To achieve this goal, it must investigate the road risks essential metrics that are employed to assess their efficacy and develop a decision-maker model that examines the importance of various hazards' impacts.

## 2. EFFECTIVE ROAD RISK FACTORS

After examining the implementation of occupational safety measures in new building projects in Iraq and comparing it to developed and neighboring countries, the researcher discovered a significant disparity in the level of safety conditions. This highlights the urgent requirement for a concise and easily accessible resource that local engineers can utilize on-site to ensure safety in their projects. To conduct a case study, the researcher examined a large-scale project in the United Arab Emirates **(Sawsan et al., 2014)**. This project prioritized the highest levels of safety criteria. Although this case study may not be directly related to projects in Iraq, we aspire to enhance the level of work in Iraq in the coming times. Upon observing the administrative processes and the assessment of the severity of each stage of the work, a clear understanding was formed regarding the most hazardous scenarios in projects involving multi-story buildings. To identify multiple solutions to the risk, researchers gathered data on 46 cases, including their ratings and the type of perceived danger in each case. They then conducted a poll, using a specific format, targeting the most important specialized institutions and enterprises operating in Iraq and the United Arab Emirates. Ultimately, the researcher compiles the findings and develops a software application that can be utilized by any user on their personal computer to analyze the anticipated risk, learn strategies to mitigate it and understand how to effectively manage it in the event of its occurrence. The majority of fatal accidents, that result in death, occur in the field of building activity. These accidents can be attributed to various factors, including a lack of worker expertise and non-compliance with safety regulations, particularly among younger workers. This study aims to examine the correlation between worker age and the frequency of injuries and accidents at the worksite. Additionally, it seeks to identify the causes of these injuries and propose effective solutions to mitigate or prevent work-related risks.

Additionally, the research demonstrates the fundamental principles of safety standards necessary for gaining a comprehensive understanding of the subject under investigation. A questionnaire was devised to gather information and subsequently analyze it statistically to derive conclusions and recommendations that may help reduce the incidence of work-related accidents at construction sites **(Gransberg et al., 2018)**. The risk factors identified in the study conducted by Yousri et al. in 2023. The risk factors identified in the study. They provided a thorough analysis of the current literature on the subject and took a comprehensive approach to addressing geotechnical concerns, rather than focusing on specific elements **(Yousri et al., 2023)**. The 27 risk indicators identified by Kerim Koc et al. in their study **(Koc et al., 2020)** have been meticulously defined and validated by specialists. The next phase of this research will involve seeking the help of experts to determine the hazards involved in transportation projects. A thorough compilation of 27 risk markers was created through an extensive literature search. Afterwards, a survey was administered to collect feedback from professionals engaged in various infrastructure development endeavors in Iraq. **Table 1** provides a concise overview of these risk variables.

**Table 1.** Type of Risk **(Koc et al., 2020; Gurgun et al., 2020)**.

| **Type of Risk** | **Factor** | **Sub-factors** |
|---|---|---|
| R1- Design Risk | 1-Working (Construction) Drawings Delay in final approval of detailed design<br>2-Changes in design and construction standards during the Construction Period | 1-Engineer skills<br>2-Available technology for calculation and design<br>3-clearance of project requirement |
| R2- Site Risk | 1-Access risks<br>2-Site Security<br>3-Cultural/archaeological/ heritage<br>4-Environmental<br>5-Geotechnical and ground/soil conditions<br>6-Water/air/soil pollution – unknown pre-existing<br>7-Undisclosed Latent defects (Existing infrastructure) | 1-Rainfall intensity<br>2-Occurrence of unexpected events like fire, flooding and landslides<br>3-Level of groundwater table higher than expected<br>4-Design change in the road pavement<br>5-The prescribed soil treatment method was not suitable for a particular site condition<br>6-De-watering due to seepage problems |
| R3-Construction Risk | Labor disputes | 1-Lack of labor factor<br>2-Low labor productivity<br>3-Workplace accidents<br>4-Resource mobilization is slow<br>5-Limitations of the use of technology<br>6-Understanding of the methods of work |
| | material availability | 1-Availability of certain materials in the market<br>2-Delay of material delivery to a location<br>3-Quality of materials does not meet specifications<br>4-Rising market prices |

| | | |
|---|---|---|
| | Control system factor and work evaluation | 1-Accuracy of construction methods<br>2-Supervision is not optimal<br>3-Completeness of the contract addendum<br>4-No test case is performed |
| | Managerial factors | 1-Contractor experience<br>2-Contractor productivity is not optimum<br>3-Slow decision making<br>4-Poor management on the field |
| | Supervision factors | 1-Lack of supervision of sub-contractors and suppliers<br>2-Lack of adequate information from the consultant<br>1-Weaknesses in supervision by the owner, field supervisors, and supervisory consultants<br>2-Ratio of supervisors and number of packages |
| | Equipment used becomes prematurely obsolescent | 1-Lack of equipment in the field<br>2-Delay in delivery/supply of equipment<br>3-Productivity of equipment<br>4-Ability to operate equipment |
| | Financial factor | 1-Payment of work is late<br>2-Cost swelling<br>3-Contractor’s financial ability |

The works illustrate a correlation between the meteorological conditions in the northern region and those in the northern part of Iraq. In the following sections, we will examine the importance of each risk factor in the project's financial resources and timeline. The region was divided into separate portions across the Iraqi land by the specialists, considering geotechnical concerns such as groundwater level and depth, regional patterns of its movement, changes in its quality (specifically salinity), and its suitability for various applications. The choice of these portions was focused on their versatility for multiple purposes. Research has revealed that Iraq is susceptible to 15 distinct types of natural hazards. The quadrangles that encompass all of Iraq are distributed from 39 different locations. In addition, a comprehensive Geological Hazards Map of Iraq has been created, along with the compilation of weather data. Currently, there is a loss of accessible geological hazard data in Iraq **(Sissakian et al., 2012)**. An individual examination was conducted on the characteristics of each region. The discussed topics encompass groundwater recharge, the flow of high-quality groundwater, the hydraulic characteristics of groundwater basins, challenges within the groundwater sector, and the generation of novel concepts. Due to the country's distinct physical, structural, geographical, and hydrogeological characteristics, it is partitioned into seven distinct hydrogeological regions. The hydrogeological and hadrochemical specifications of each location exhibit effective variations from one another **(Ahad et al., 2011; Fouad et al., 2015)**.

## 3. MATERIAL AND METHODS

The main goal of this study is to determine the most significant and valuable aspects that contribute to risks in building projects. Only a proficient and seasoned team is capable of carrying out the rating. Researchers can utilize the Delphi technique to acquire material that

is open to multiple interpretations. If you wish to employ the Delphi technique as described by **(Sunke et al., 2009; López et al., 2021)**, the following are a few justifications:
The Delphi approach is widely utilized for making predictions in both the technical sphere and the corporate world. It has dominion over 90% of research and forecasts about technology.
Before the commencement of the inquiry, the Delphi technique was conceived, developed, and employed, with particular emphasis on topic selection and periods.
Additional safety precautions include maintaining a low response rate, ensuring that external factors do not impact the responses, and inquiring about panelists' lack of expertise on the topic rather than soliciting their expert opinions **(Emerson, 2006)**.
It was particularly intrigued by the responses provided by specialists who are presently engaged in initiatives in Iraq. A scale ranging from 0 to 5 was provided to them to rate the level of danger associated with various things. A rank of 0 indicates that the risk has a negligible impact in terms of both frequency and severity. Conversely, a rank of 5 indicates that the risk has the greatest influence in terms of both frequency and impact. The scale was designed to provide a wider range of choices for selecting the statistical method **(Nguyen et al., 2014; Mahmoudkelaye et al., 2018**).

## 4. WEIGHTED PRODUCT METHOD (WPM)

The weighted product model (WPM) is a widely recognized approach for multi-criteria decision analysis (MCDA) and multi-criteria decision-making (MCDM). The Weighted Product (WP) approach is a component of the decision-making model that uses multiplication to connect attribute ratings. The multiplication of attributes is enhanced by weight, which presents as a positive ranking factor, while the cost attribute is adversely ranked based on attribute ranking **(Sinaga et al., 2022)**. The capacity to utilize relative values instead of absolute ones is a notable target of this strategy. The computations of this method can be observed in the subsequent example, which is presented clearly and directly. We employ the same numerical values as those in the numerical example of the weighted sum model as our information. The subsequent numerical data is replicated for the sake of convenience in referencing.
The computation steps of the WPM method are as follows **(Supriyono et al., 2018)**:

**1**. List the criteria used in the computation based on the weight and category.

**2**. Calculate the relative weight of j -the criteria to the total weight of all criteria using the following formula:

$$W_J^- = \frac{W_J}{\sum_{J=1}^{N} W_J} \qquad (1)$$

Where $\sum_{J=1}^{N} W_J = 1$

**3**. Calculate the preference value of every I -the alternative using **Eq. (2)**.

$$S_i = \prod_{j=1}^{N} x_{ij}^{W_J^-} \qquad (2)$$

Where the value of w is positive if the criteria is a benefit otherwise its value is negative.

**4**. Calculate the relative preference value of each alternative to all alternatives using **Eq. (3)**.

$$V_i = \frac{S_i}{\sum_{i=1}^{M} S_i} \quad (3)$$

**5**. The higher the V value, the better the alternative.

## 5. RELATIVE IMPORTANT INDEX (RII)

During the risk management process, the judgments made by decision-makers are influenced by their risk tolerance, the volume and severity of the cost, and other relevant factors. After evaluating the risks, it is necessary to determine their level of acceptability. The decision-maker's willingness to offer a choice depends on the level of risk that an individual, customer, or society is willing to tolerate **(Rashid et al., 2023; Alfahad et al., 2024)**. Every aspect, including money, timing, technical solutions, and building methods, should be determined according to an acceptable level of risk factor **(Mirza et al., 2010)**. In a study conducted in 2012 by Bari, the RII test was employed to assess the impact of risk factor variables on survey replies. This was achieved by assigning a specific value to each variable to represent its level of risk **(Bari et al., 2012)**. It employed the subsequent foundation to ascertain the Relative Importance Index (RII) **(Poleankin et al., 2020)**:

$$RII = \sum(PiUi)/Nn \quad (4)$$

RII = relative importance index
Pi = respondent's rating of risk factors
Ui = number of respondents placing identical weighting/rating on the factor
N = sample size people who responded to the survey
n = the highest attainable score for each factor

This method is used to rank the factors to specify the effective factors that can affect the delay in construction processes. Khairullah in 2023 proposed the primary obstacles encountered in the execution of significant turn-key projects in Iraq, with a particular focus on intricate and rapidly evolving projects. Project completion delays diminish the advantages of these projects, particularly those that help citizens in the health sector **(Khairullah et al., 2023)**. The case study encompassed the construction of multi-bed hospitals throughout many governorates in Iraq, also, Mohammed et al., 2024, utilized Building Information Modeling (BIM) in the construction industry owing to its advantageous features that span the whole Project Life Cycle. BIM can replicate buildings across PLC, identify and resolve problems, and enhance building visualization to accurately represent project details during construction. BIM facilitates project management by identifying conflicts, cost overruns, and schedule delays. This effort aims to provide efficient Building Information Modeling (BIM) systems for building projects in Iraq **(Mohammed et al., 2024)**.

### 5.1 Collecting the Data

Multiple methods were used to find these characteristics because they are so important for Iraqi building projects. These methods included reading academic literature, filling out a questionnaire, and talking to experts.

## 5.2 Analysis of Questionnaire

In the present work, the areas considered in data collection in the study include company size and level, job title, experience, and years of working on projects. The sample size was one hundred and three persons classified as below:

### 5.2.1 Type of Company

The employment distribution of the respondents is presented in **Table 2** as follows: three organizations contracted with the government and four organizations utilized subcontractors. While this competency is present in all domains, it is assessed most extensively in the project planning and preliminary cost estimation sections. Knowledge of the process of assembling the components and determining the ultimate cost promptly ensues thereafter. The preponderance of responses originating from contracting firms as opposed to consultancy firms can be attributed to the proliferation of contracting enterprises in Iraq.

**Table 2.** The Distribution of Questionnaires by Firm Type.

| No. | Company types | No. of companies |
|---|---|---|
| 1 | government companies | 3 |
| 2 | subcontractors | 4 |

### 5.2.2 Job Title

The study included participants from several engineering disciplines, as evidenced by **Table 3**. The composition of the workforce was as follows: project managers accounted for 33% of the total, site engineers accounted for 32%, planning engineers accounted for 18%, and consulting engineers accounted for 17% with the total size of samples 103. Project managers, as the most senior members of the team, have access to all project-related financial data, as demonstrated in this example.

**Table 3.** The Distribution of the Questionnaire by Job Title.

| No. | Job title | No. of engineers |
|---|---|---|
| 1 | Consultant engineers | 17 |
| 2 | Project managers | 34 |
| 3 | Planning engineers | 19 |
| 4 | Site engineers | 33 |
| total | | 103 |

### 5.2.3 Years of Building Project Experience

The subjects' work experience is shown in **Table 4**. Fifteen percent of them had more than fifteen years of experience, sixty percent had about ten years of experience, and twenty-five percent had less than five years of experience. This means that most of the people who answered have enough knowledge about construction to be able to name the key factors that affect project prices. It was discovered that a large percentage of them had strong experience in the construction area and held advanced positions in their jobs, which adds to the logic and reality of the survey results to some extent.

**Table 4**. The Distribution of Questionnaires Based on the number of years of experience.

| No. | Experience time | Years of experience |
|---|---|---|
| 1 | High experience | more than 15 years |
| 2 | Moderate experience | between 5 to 10 years |
| 3 | junior engineers | less than 5 years |

## 5.3 Risk Identification

The study's main concept is initially introduced, subsequently followed by the inquiries and interviews. The methodology section of the essay elucidates the procedures that were employed to investigate the duties of project managers in construction projects in Iraq. When constructing a building, it is normal to employ professional architects and engineers. These projects may require the employment of general contractors and architects. Constructing a little edifice necessitates significantly less exertion and time compared to constructing a substantial and intricate one. In addition to serving as documentation and evidence of compliance, the regulations regarding ranking systems are often followed during the construction process. The resistance of a structure or its components is evaluated using a comprehensive scoring system during the design **(Shadhar et al., 2018)**, construction, manufacturing, and erection stages. For a project to be completed within the allocated time and budget, it is crucial to effectively monitor and manage several aspects such as the grading system, credit registration and documentation, communication with stakeholders, and team members' duties. The finalized survey is presented in **Tables 5-9**, below.

**Table 5.** Risks resulting from rudderless designs.

| | |
|---|---|
| Q1-1 | Designs are submitted on time according to the contract with the consulting office. |
| Q1-2 | The designs provided are identical to the road tracks. |
| Q1-3 | The designs presented are compatible with preliminary soil tests in all areas. |
| Q1-4 | The designs presented cover preliminary calculations of road construction requirements. |
| Q1-5 | The roads pass through unsafe areas. |
| Q1-6 | We often find errors in paths during execution. |
| Q1-7 | We often find a difference between soil investigations and percussion paths. |
| Q1-8 | We often need to change orders due to errors in calculating quantities. |
| Q1-9 | Paragraphs are often created to carry out the work in an integrated manner. |
| Q1-10 | We often find soil that needs to be replaced during implementation. |

**Table 6.** The impact of the site on the flow of work.

| | |
|---|---|
| Q2-1 | In carrying out road works, the movement of machinery and equipment is calculated in terms of the starting point. |
| Q2-2 | In carrying out road works, the movement of machinery and equipment must be at calculated speeds. |
| Q2-3 | In carrying out road works, the movement of machinery and equipment is calculated at rest points. |
| Q2-4 | In carrying out road works, the movement of machinery and equipment is calculated at accommodation points. |

| | |
|---|---|
| Q2-5 | In carrying out road works, the movement of machinery and equipment is calculated in terms of dividing the distances for each work team. |
| Q2-6 | The protection of machinery and workers shall be carefully calculated. |
| Q2-7 | Existing clans are often cooperative and offer great facilities. |
| Q2-8 | Disagreements often occur between clans and workers. |
| Q2-9 | Torrential rains do not hinder the progress of work. |
| Q2-10 | Landslides are a major cause of work interruption. |

**Table 7.** The influence of cadres on the implementation of the contractual schedule of quantities.

| | |
|---|---|
| Q3-1 | In general, there is a shortage of specialized workers. |
| Q3-2 | Specialized labor is expensive for road projects. |
| Q3-3 | Available labor is low in productivity. |
| Q3-4 | Accidents often occur that hinder the progress of work. |
| Q3-5 | Work accidents cause projects huge losses. |
| Q3-6 | The required resources, such as workers and equipment, are available at all stages of work. |
| Q3-7 | The resources required are very expensive. |
| Q3-8 | The available workers can use the latest machines. |
| Q3-9 | Engineers are generally proficient in using GPS and Total Station. |
| Q3-10 | Topographic maps are available, easy to read, and useful. |
| Q3-11 | The working methods are standard and easy. |
| Q3-12 | In road projects, a routine and standardized work progress schedule |
| Q3-13 | All materials for road construction are available locally. |
| Q3-14 | Contracting methods for getting materials to the work site are ineffective. |
| Q3-15 | Materials are often delayed in arriving on-site. |
| Q3-16 | Materials often fail to meet specifications. |
| Q3-17 | Processed materials are often expensive. |
| Q3-18 | Market prices are often variable and cause losses to the project. |

**Table 8.** The effect of administrative efficiency on the quality of work completion.

| | |
|---|---|
| Q4-1 | The methods used in implementing projects are considered accurate from an engineering standpoint. |
| Q4-2 | Weak supervision causes major financial losses to the project. |
| Q4-3 | Weak supervision causes delays in the project work schedule. |
| Q4-4 | A contract addendum is a major reason for reducing contractors' profits. |
| Q4-5 | Contract attachment is often due to poor schemes. |
| Q4-6 | The contract addendum is a natural consequence of the lack of laboratory test results for the project. |
| Q4-7 | Weak supervision may not be a reason for obstructing work according to plans. |
| Q4-8 | The contractor's experience is an essential factor in the success of the project. |
| Q4-9 | Contractor productivity is a major reason for the success of the project. |
| Q4-10 | The contractor's productivity depends on his experience. |
| Q4-11 | Contractor productivity depends on available capital and cash flows. |

| | |
|---|---|
| Q4-12 | Projects managed by a specialized road engineering contractor are characterized by good performance. |
| Q4-13 | Contractor productivity depends on the good performance of project workers. |
| Q4-14 | Contractor productivity increases due to the speed of decision-making. |
| Q4-15 | Contractor productivity increases due to accurate decision-making. |
| Q4-16 | Good decision-making depends on the project manager. |
| Q4-17 | Good decision-making depends on the contractor's experience. |
| Q4-18 | The administrative structure of the project is a critical factor for the success of the project. |
| Q4-19 | The project management structure depends on the project manager. |
| Q4-20 | The project's administrative structure depends on the contractor's experience. |
| Q4-21 | The administrative structure of the project depends on the experience of the project workers. |
| Q4-22 | Weak project management structure causes project loss. |
| Q4-23 | The weak administrative structure of the project caused the project to be delayed. |
| Q4-24 | Poor follow-up causes delays in the completion of work. |
| Q4-25 | Poor follow-up causes additional expenses. |
| Q4-26 | Poor follow-up causes a weakness in the cash flow allocated to the project. |
| Q4-27 | Weak consulting staff is a direct reason for project disruption. |
| Q4-28 | The weakness of the consulting staff is determined by resolving the obstacles during the implementation of the work. |
| Q4-29 | The weakness of the consulting staff extends from project design until the completion of work implementation. |
| Q4-30 | Weak supervision by the project beneficiary is one of the biggest reasons for project delays. |
| Q4-31 | The precision of the beneficiary's staff is a success factor for the project. |
| Q4-32 | Poor management of beneficiary cadres is a major reason for project delays. |
| Q4-33 | Slow decision-making by the beneficiaries causes the project significant financial consequences. |
| Q4-34 | The number of supervisors is proportional to the size of the project. |
| Q4-35 | The ratio of the number of supervisors must equal the number of work team groups. |
| Q4-36 | Increasing the number of supervisors causes confusion in work management. |

**Table 9.** The impact of machinery management on the work progress schedule.

| | |
|---|---|
| Q5-1 | The type of equipment used is a major reason for the success of the project. |
| Q5-2 | The efficiency of the equipment must be proportional to the type of work and the time required to complete the work. |
| Q5-3 | Equipment productivity is the primary factor for implementing technical specifications. |
| Q5-4 | The equipment used must be completely new. |
| Q5-5 | Old equipment cannot be used. |
| Q5-6 | The size of the project is proportional to the type of equipment used. |
| Q5-7 | The cost of equipment is a factor in the success of the project. |
| Q5-8 | The equipment must be owned by the implementing company for the project to be successful. |
| Q5-9 | Delayed arrival of equipment causes loss to the project. |
| Q5-10 | There is a direct relationship between the type of equipment, the size of the machinery, and the time the equipment arrives at the project. |

| | |
|---|---|
| Q5-11<br>Q5-12 | The most productive machines are the ones with the highest technology.<br>The size and number of machines are determined according to the planned productivity in the work progress schedule. |
| Q5-13 | Balancing the number of machines for each paragraph of the contractual bill of quantities is the basis for the success of the work. |
| Q5-14 | The skill of workers in using machinery is a decisive factor in increasing productivity. |
| Q5-15 | The skill of the worker depends on the type of equipment and its techniques. |
| Q5-16 | Market inflation is a major reason for companies' reluctance to offer competitive prices. |
| Q5-17 | Cost inflation can be contained by reducing the number of workers. |
| Q5-18 | Cost inflation relates to materials only and not to labor wages. |
| Q5-19 | Cost inflation is dealt with by the contractor with the amount of capital invested. |
| Q5-20 | Increasing the financial capacity of the contractor increases profits. |

The present process is applied using the Delphi method. The number of specialized teams needed to execute the Delphi Method is proportional to the magnitude of the construction endeavor one plans to embark upon. The extent to which a group can be gathered is determined by the specifications of the governing bodies and the available resources. Creating this group through a random selection process from the events is not a viable approach. In contrast to traditional approaches to data collection, the aim in this instance is not to discern a subset of the population that precisely represents the entire population **(Skulmoski et al., 2007; Lilja, 2011)**. To ensure that the Delphi technique produces valid results, it is crucial to assume that all respondents possess specialized knowledge in the relevant field. The authority to ascertain the level of proficiency that an organization possesses in a specific domain ought to rest with those tasked with supervising the evaluation procedure. After the conclusion of the specialist selection procedure, each member of the team is provided with a form.

## 6. RESULTS AND DISCUSSION

This strategy aims to maximize financial profits by leveraging the enterprise's influence on various socioeconomic, environmental, and governmental aspects. The main objective of sustainability risk management is to attain an optimal equilibrium between mitigating adverse outcomes and fostering favorable outcomes. This article identifies some potential hazards that could hinder the progress of construction projects in Iraq. Implementing this approach decreases the probability of supply chain disruptions caused by occurrences such as natural calamities or labor conflicts. The first step in investigating the road risks is the mean of the risks evaluation as shown in **Table 10**.

The results observed eight effective factors. The factors are Q1 9 (new orders are often created to carry out the work in an integrated manner), Q2 6 (The insurance of machinery and workers shall be carefully calculated), Q3 3 (Available labor is low in productivity), Q4 3 (Weak supervision causes delays in the project work schedule), Q5 3 (Equipment productivity is the primary factor for implementing technical specifications0, Q5 11 (The most productive machines are the ones with the highest technology, Q5 12 (The size and number of machines are determined according to the planned productivity in the work progress schedule), Q5 15 (The skill of the worker depends on the type of equipment and its techniques).

**Table 10.** The effectiveness is based on mean results.

| Factor | mean | Factor | mean | Factor | mean | Factor | mean | Factor | mean |
|---|---|---|---|---|---|---|---|---|---|
| Q1 1 | 3.8 | Q2 10 | 3.09 | Q4 1 | 4.05 | Q4 20 | 3.77 | **Q5 3** | **3.93** |
| Q1 2 | 3.88 | Q3 1 | 4.01 | Q4 2 | 3.97 | Q4 21 | 2.83 | Q5 4 | 3.9 |
| Q1 3 | 4.04 | Q3 2 | 3.93 | **Q4 3** | **4.23** | Q4 22 | 3.82 | Q5 5 | 3.78 |
| Q1 4 | 1.88 | **Q3 3** | **4.2** | Q4 4 | 3.94 | Q4 23 | 3.69 | Q5 6 | 3.86 |
| Q1 5 | 4.07 | Q3 4 | 3.9 | Q4 5 | 3.68 | Q4 24 | 3.77 | Q5 7 | 2.6 |
| Q1 6 | 3.82 | Q3 5 | 3.64 | Q4 6 | 2.72 | Q4 25 | 3.98 | Q5 8 | 3.89 |
| Q1 7 | 1.99 | Q3 6 | 2.75 | Q4 7 | 4.13 | Q4 26 | 3.72 | Q5 9 | 3.82 |
| Q1 8 | 4.19 | Q3 7 | 4.06 | Q4 8 | 4 | Q4 27 | 2.76 | Q5 10 | 3.9 |
| **Q1 9** | **4.26** | Q3 8 | 3.96 | Q4 9 | 4.2 | Q4 28 | 3.82 | **Q5 11** | **3.93** |
| Q1 10 | 3.6 | Q3 9 | 4.16 | Q4 10 | 3.99 | Q4 29 | 4 | **Q5 12** | **3.93** |
| Q2 1 | 3.91 | Q3 10 | 3.95 | Q4 11 | 3.73 | Q4 30 | 3.74 | Q5 13 | 3.82 |
| Q2 2 | 1.99 | Q3 11 | 3.69 | Q4 12 | 3.99 | Q4 31 | 3.82 | Q5 14 | 3.85 |
| Q2 3 | 3.83 | Q3 12 | 3.95 | Q4 13 | 3.73 | Q4 32 | 2.81 | Q5 15 | 3.93 |
| Q2 4 | 1.84 | Q3 13 | 3.69 | Q4 14 | 3.98 | Q4 33 | 2.86 | Q5 16 | 3.86 |
| Q2 5 | 4 | Q3 14 | 2.8 | Q4 15 | 3.72 | Q4 34 | 2.96 | Q5 17 | 3.91 |
| **Q2 6** | **4.34** | Q3 15 | 2.73 | Q4 16 | 2.76 | Q4 35 | 3.82 | Q5 18 | 2.91 |
| Q2 7 | 3.04 | Q3 16 | 3.74 | Q4 17 | 2.76 | Q4 36 | 2.91 | Q5 19 | 3.82 |
| Q2 8 | 4.25 | Q3 17 | 2.76 | Q4 18 | 2.9 | Q5 1 | 3.9 | Q5 20 | 2.86 |
| Q2 9 | 3.91 | Q3 18 | 2.9 | Q4 19 | 2.95 | Q5 2 | 3.85 | | |

The concerns listed below in **Table 11** were determined to have the greatest significant impact, according to the RII results. It offers a thorough method of conflict monitoring that considers various road project difficulties. This outcome is based on information gathered from outside sources for road projects. The results observe the same effective factors gained by the mean method. This indicates that these two methods can guide the decision-makers to the same risk estimation. For that, the researchers have used another effective method to increase the accuracy of detecting the effective risks. The WPM method presents new results as shown in **Table 12**.

The results observed Q1 6 (often find errors in paths during execution), Q2 10 (often find soil that needs to be replaced during implementation), Q3 6 (The required resources, such as workers and equipment, are available at all stages of work), Q4 21 (The administrative structure of the project depends on the experience of the project workers) and Q5 7 (The cost of equipment is a factor in the success of the project). These factors represent the risks in the Iraqi road work environment which can cause a huge obstacle in the project.

**Fig. 1** shows a comparison between the ranks of effective factors gained by using the WPM method. To understand the differences between the RII method and the WPM method, **Fig. 2** presents the effective factors of the RII method and can be compared with the WPM method. The purpose of the two methods is to enhance comprehension of the identified hazards, gather data for the following risk assessment, and offer potential solutions to the issues it reveals.

**Table 11.** The effective factors based on RII results.

| **Factor** | **RII** | **Factor** | **RII** | **Factor** | **RII** | **Factor** | **RII** | **Factor** | **RII** |
|---|---|---|---|---|---|---|---|---|---|
| Q1 1 | 0.760 | Q2 10 | 0.618 | Q4 1 | 0.81 | Q4 20 | 0.754 | **Q5 3** | **0.786** |
| Q1 2 | 0.776 | Q3 1 | 0.802 | Q4 2 | 0.794 | Q4 21 | 0.566 | Q5 4 | 0.78 |
| Q1 3 | 0.808 | Q3 2 | 0.786 | **Q4 3** | **0.846** | Q4 22 | 0.764 | Q5 5 | 0.756 |
| Q1 4 | 0.376 | **Q3 3** | **0.84** | Q4 4 | 0.788 | Q4 23 | 0.738 | Q5 6 | 0.772 |
| Q1 5 | 0.814 | Q3 4 | 0.78 | Q4 5 | 0.736 | Q4 24 | 0.754 | Q5 7 | 0.52 |
| Q1 6 | 0.764 | Q3 5 | 0.728 | Q4 6 | 0.544 | Q4 25 | 0.796 | Q5 8 | 0.778 |
| Q1 7 | 0.398 | Q3 6 | 0 | Q4 7 | 0.826 | Q4 26 | 0.744 | Q5 9 | 0.764 |
| Q1 8 | 0.838 | Q3 7 | 0.812 | Q4 8 | 0.8 | Q4 27 | 0.552 | Q5 10 | 0.78 |
| **Q1 9** | **0.852** | Q3 8 | 0.792 | Q4 9 | 0.84 | Q4 28 | 0.764 | **Q5 11** | **0.786** |
| Q1 10 | 0.720 | Q3 9 | 0.832 | Q4 10 | 0.798 | Q4 29 | 0.8 | **Q5 12** | **0.786** |
| Q2 1 | 0.782 | Q3 10 | 0.79 | Q4 11 | 0.746 | Q4 30 | 0.748 | Q5 13 | 0.764 |
| Q2 2 | 0.398 | Q3 11 | 0.738 | Q4 12 | 0.798 | Q4 31 | 0.764 | Q5 14 | 0.77 |
| Q2 3 | 0.766 | Q3 12 | 0.79 | Q4 13 | 0.746 | Q4 32 | 0.562 | **Q5 15** | **0.786** |
| Q2 4 | 0.368 | Q3 13 | 0.738 | Q4 14 | 0.796 | Q4 33 | 0.572 | Q5 16 | 0.772 |
| Q2 5 | 0.8 | Q3 14 | 0.56 | Q4 15 | 0.744 | Q4 34 | 0.592 | Q5 17 | 0.782 |
| **Q2 6** | **0.868** | Q3 15 | 0.546 | Q4 16 | 0.552 | Q4 35 | 0.764 | Q5 18 | 0.582 |
| Q2 7 | 0.608 | Q3 16 | 0.748 | Q4 17 | 0.552 | Q4 36 | 0.582 | Q5 19 | 0.764 |
| Q2 8 | 0.85 | Q3 17 | 0.552 | Q4 18 | 0.58 | Q5 1 | 0.78 | Q5 20 | 0.572 |
| Q2 9 | 0.782 | Q3 18 | 0.58 | Q4 19 | 0.59 | Q5 2 | 0.77 | | |

**Table 12.** The effective factors based on WPM results.

| Factor | wpm | Factor | wpm | Factor | wpm | Factor | wpm | Factor | wpm |
|---|---|---|---|---|---|---|---|---|---|
| Q1 1 | 0.261 | **Q2 10** | **0.313** | Q4 1 | 0.282 | Q4 20 | 0.316 | Q5 3 | 0.000 |
| Q1 2 | 0.256 | Q3 1 | 0.337 | Q4 2 | 0.000 | **Q4 21** | **0.531** | Q5 4 | 0.000 |
| Q1 3 | 0.000 | Q3 2 | 0.262 | Q4 3 | 0.000 | Q4 22 | 0.000 | Q5 5 | 0.319 |
| Q1 4 | 0.275 | Q3 3 | 0.000 | Q4 4 | 0.285 | Q4 23 | 0.415 | Q5 6 | 0.000 |
| Q1 5 | 0.214 | Q3 4 | 0.322 | Q4 5 | 0.401 | Q4 24 | 0.316 | **Q5 7** | **0.494** |
| **Q1 6** | **0.303** | Q3 5 | 0.429 | Q4 6 | 0.467 | Q4 25 | 0.250 | Q5 8 | 0.238 |
| Q1 7 | 0.277 | **Q3 6** | **0.547** | Q4 7 | 0.000 | Q4 26 | 0.389 | Q5 9 | 0.000 |
| Q1 8 | 0.000 | Q3 7 | 0.000 | Q4 8 | 0.000 | Q4 27 | 0.466 | Q5 10 | 0.000 |
| Q1 9 | 0.000 | Q3 8 | 0.000 | Q4 9 | 0.000 | Q4 28 | 0.000 | Q5 11 | 0.000 |
| Q1 10 | 0.278 | Q3 9 | 0.291 | Q4 10 | 0.000 | Q4 29 | 0.000 | Q5 12 | 0.000 |
| Q2 1 | 0.289 | Q3 10 | 0.000 | Q4 11 | 0.331 | Q4 30 | 0.348 | Q5 13 | 0.319 |
| Q2 2 | 0.309 | Q3 11 | 0.359 | Q4 12 | 0.000 | Q4 31 | 0.000 | Q5 14 | 0.280 |
| Q2 3 | 0.310 | Q3 12 | 0.000 | Q4 13 | 0.331 | Q4 32 | 0.450 | Q5 15 | 0.000 |
| Q2 4 | 0.285 | Q3 13 | 0.359 | Q4 14 | 0.250 | Q4 33 | 0.428 | Q5 16 | 0.000 |
| Q2 5 | 0.000 | Q3 14 | 0.541 | Q4 15 | 0.389 | Q4 34 | 0.367 | Q5 17 | 0.000 |
| Q2 6 | 0.000 | Q3 15 | 0.508 | Q4 16 | 0.466 | Q4 35 | 0.000 | Q5 18 | 0.418 |
| Q2 7 | 0.311 | Q3 16 | 0.000 | Q4 17 | 0.484 | Q4 36 | 0.401 | Q5 19 | 0.000 |
| Q2 8 | 0.000 | Q3 17 | 0.508 | Q4 18 | 0.492 | Q5 1 | 0.000 | Q5 20 | 0.446 |
| Q2 9 | 0.261 | Q3 18 | 0.516 | Q4 19 | 0.474 | Q5 2 | 0.280 | | |

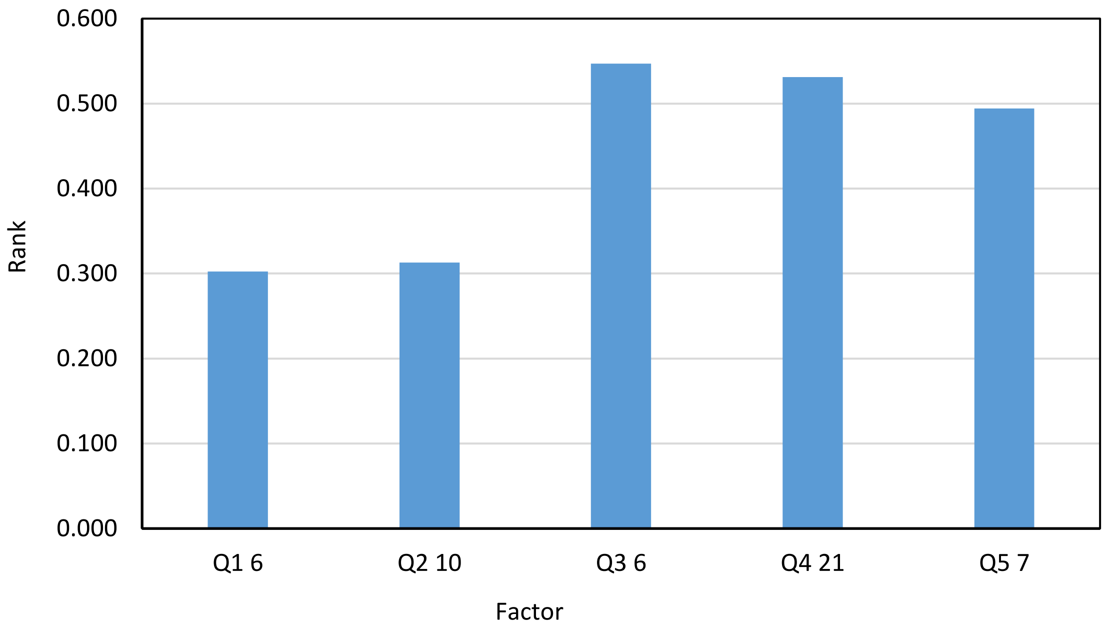


**Figure 1.** Comparison between the ranks of effective factors using the WPM method.

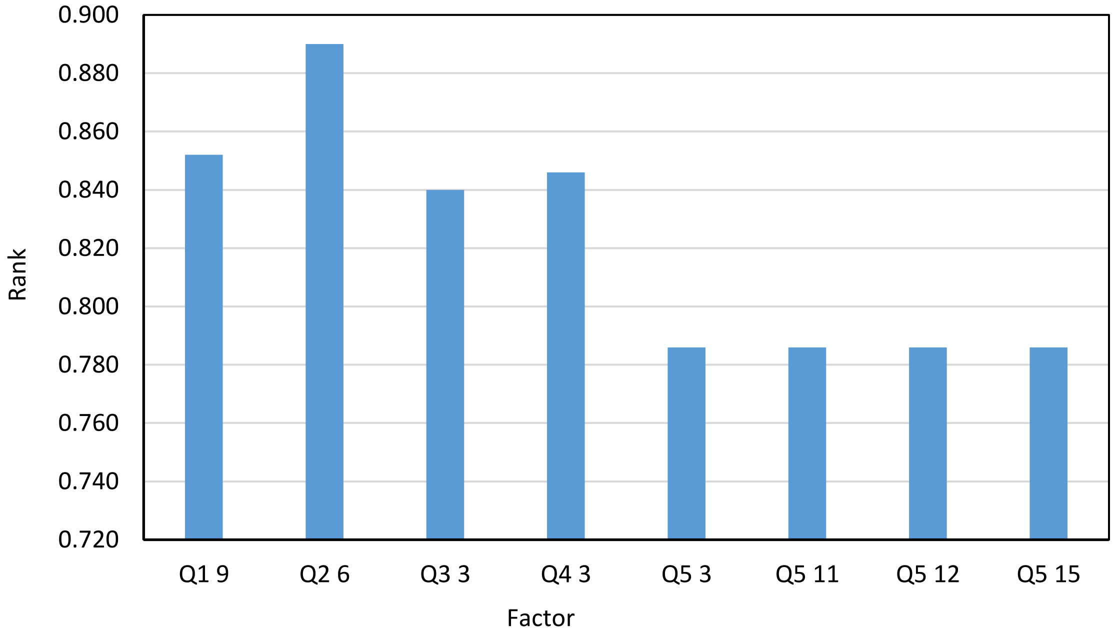


**Figure 2.** Comparison between the ranks of effective factors using the RII method.

Risk analysis offers a structured approach and specific methods for evaluating risks by outlining the sequence of events that could lead to harm. It is crucial to carefully analyze and record any possible reactions and consequences. Other potential events that could trigger or exacerbate a danger should be taken into account during the risk assessment. Following the risk identification step, the initial step in risk analysis is to thoroughly investigate all identified dangers. The results presented two factors that represent the main effective factors affecting road construction projects.

1- The insurance of machinery and workers shall be carefully calculated.

2- The required resources, such as workers and equipment, are available at all stages of work.
The third round of expert survey proposed a practical opinion and the final results taken from the final approach as in the next step.

## 7. CONCLUSION

The road construction sector in Iraq has a long history of neglecting risk management measures and beyond budgetary limitations. Considerable scholarly effort has been devoted to examining the factors that contribute to the hazards associated with road projects. The existing literature lacks substantial information regarding the correlation between the benefits and drawbacks of a solution for a road construction company's operations and competitiveness, and how it relates to or diverges from strategic growth. Analyzing this correlation by assessing the potential hazards is essential for comprehending the importance of incorporating risk factors into decision-making and identifying the underlying causes of various occurrences. The evaluation of hazards relies on a road construction organization's ability to efficiently oversee and handle its operational tasks. The primary investigation assessed the impact of implementing risk management strategies on performance indicators through a combination of surveys, expert opinions, interviews, and exploratory research, drawing on prior studies of construction projects. Reformatting the user's content into an academic style is not feasible due to its highly condensed nature. The initial results were obtained by calculating the average risk assessment. Next, the second group of results was determined by identifying the RII effect.

1- The RII results present that the insurance of machinery and workers has the highest rank with a value of 0.868.
2- The WPM method was applied to the collected data and determined that the availability of essential resources such as labor and equipment at all phases of activity, had a value of 0.547.
3-The WPM results yielded more practical and realistic outcomes.

To ensure the Iraqi road construction sector is free from unqualified personnel and to enhance the productivity of construction workers, particularly foremen, it is crucial to prioritize training and ongoing professional development for individuals in supervisory roles on construction sites. For that, it is important to develop an expert system that can collect the most important factors for road construction projects.

## NOMENCLATURE

| Symbol | Description | Symbol | Description |
|---|---|---|---|
| Wj | Denotes the relative weight | Pi | Respondent's rating of factor effect |
| Si | The preference value | Ui | Number of respondents placing identical weighting/rating on the factor effect |
| xij | The performance of alternative | N | Sample size people responded to the survey |
| Vi | Relative preference value | n | The highest attainable score for each factor effect |
| RII | Relative Importance Index | | |

## Credit Authorship Contribution Statement

Ahmed M. Saleh: Writing – reviewing & editing. Mustafa A. Hilal: Supervision, reviewing, evaluation & editing

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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# تحديد المخاطر في مشاريع بناء الطرق باستخدام نموذج المنتج الموزون: العراق كدراسة حالة

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**الخلاصة**

تعتبر إدارة مخاطر مشاريع الطرق من اهم التحديات التي تعيق التطور في العالم. لذلك تهدف هذه الدراسة إلى الكشف عن العوامل الأساسية التي تساهم في المخاطر المرتبطة بمشاريع بناء الطرق في بيئة العراق وتقييمها. استخدمت الدراسة الحالية مجموعة واسعة من الأساليب والبروتوكولات لتحقيق أهدافها. استخدمت الدراسة الأولية مزيجًا من الدراسات الاستقصائية وآراء الخبراء والمقابلات والأبحاث الاستكشافية، مستفيدة من الدراسات السابقة حول مشاريع البناء، لدراسة تأثير تنفيذ الطرق المحفوفة بالمخاطر على مؤشرات الأداء. تم استخلاص المجموعة الأولية من النتائج عن طريق حساب متوسط تقدير المخاطر. وفي وقت لاحق، تم إنشاء مجموعة النتائج الثانية من خلال مؤشر الأهمية النسبية (RII). وفي طريقة RII ومتوسط النتائج وجد أن التأمين على العمال والآلات هو الأبرز. باستخدام نفس البيانات التي تم جمعها، حددت منهجية نموذج المنتج المرجح (WPM) في نهاية المطاف أن الموارد الأساسية مثل الموظفين والمعدات التي يجب الوصول إليها من خلال تمثل الآلات في جميع مراحل بناء الطرق عاملاً فعالاً رئيسياً يمكن أن يساعد في تحقيق النجاح بالمرتبة 0.868. كما تمثل ظروف العامل ومهاراته استراتيجية أخرى في المشاريع التي حصلت على رتبة 0.547. اسفرت نتائج نموذج المنتج المرجح بمخرجات أكثر دقة وعملية.

**الكلمات المفتاحية :** نموذج المنتج المرجح، مخاطر مشاريع الطرق، مؤشر الأهمية النسبية