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Prioritization of Delay Causes in Rural Road Construction Projects

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Abstract

Delays are a common and integral part of construction projects, despite their undesirable impact on costs. Several studies in the existing body of knowledge have already advocated different strategies to minimize project delays, abandonment, and cost overruns. However, existing studies have predominantly focused on urban projects, thereby depriving us of knowledge of rural projects despite their peculiarities. Therefore, the overarching aim of this study is to identify and prioritize the causes of delays in rural road construction projects in Iran, and to investigate the relationships among them using a hybrid DEMATEL-ANP decision-making framework. According to the results, "financial problems" have the most interactions with other indicators, while "inflation" is identified as the factor with the most significant influence on other indicators. Furthermore, results depict that "lack of credits" is the most effective and influential leading cause of delays in rural road construction projects. It was also indicated that initially anticipated project funds are much lower than the actual costs, due to inflation in Iran. Results obtained through can aid the recognition of the most prevalent causes of rural projects, while still accounting for the peculiarities of such projects, so that project owners can improve the robustness of planning for future projects.

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INTRODUCTION

Roads are critical contributors to the economic development of all countries and bring many social benefits by connecting regions and nations. Although road construction projects are expected to be completed within the scheduled time and budget, delays and cost overruns usually occur, especially in developing countries (Alsuliman, 2019; Aziz & Abdel-Hakam, 2016; Mahdi & Soliman, 2018; Ochieng et al., 2017; Tadewos & Patel, 2018). For instance, studies have shown that up to 80% of projects executed using traditional methods in Malaysia experience time overrun (Shehu et al., 2014). Over the years, researchers and industry professionals have identified cost, time, and quality as the most crucial factors in characterizing project success (Tadewos & Patel, 2018). Despite widespread acceptance of the need to monitor projects using the aforementioned three factors (mainly cost), it is increasingly challenging to complete projects within allocated budgets, as final costs rise during the course of the project (Plebankiewicz, 2018). This is perhaps why many projects continue to experience cost overruns and excessive delays (Habibi et al., 2018). Delay is a term commonly used in almost every facet of life, which is why it is unsurprising that there are so many variations in its definition. However, this study shall examine definitions that capture the most prevalent keywords used to describe delay. For instance, the Oxford English dictionary (2020), defines delay as "an unplanned deferment of a scheduled activity owing to an occurrence that impedes its commencement, continuation, or completion". Agyekum-Mensah and Knight (2017) also define delay as "the inability to meet the scheduled time". Similarly, describe delay as "the time overrun either beyond the completion date specified under a contract or beyond the date that the parties agreed upon for delivery of a project". The study by Arantes and Ferreira (2020) highlighted that "timely completion of a project is usually regarded as the major parameters for measuring the success of a project", which is why researchers continue to seek techniques that would help identify the antecedents of project delays at their incipient stages so that mitigation strategies can be implemented ahead of catastrophic outcomes (Durdyev & Hosseini, 2019). Although the leading causes of time and cost overruns are often the same (Yap & Skitmore, 2018), their effects vary from case to case. For instance, extension of time, cost overruns, loss of profits, disputes, out-of-sequence tasks, poor worker motivation, and substandard quality of work are among the effects of cost and time overruns (Mukuka et al., 2015; Yap Jeffrey Boon et al., 2020). Various factors are contributing to the delay, but the recurrent causes identified in the current body of knowledge include designer changes, user changes, weather, site conditions, late deliveries, and economic conditions (Assaf & Al-Hejji, 2006). While it can be argued that knowledge around the leading causes of project delays is well-established, most of the current approaches focus on simply identifying such causes of delays and their impacts on time extensions, costs and quality, but there are still significant knowledge gaps around the various facets of research related to the understanding and management of project delays. Firstly, existing studies rarely investigate how to prioritise these main causes of delay particularly based on their impacts on each other. Secondly, very few studies have actually investigated the knock-on effects that a delay factor may have on other project factors within the Middle East region, especially using Iran as case study. Thirdly and more specifically, very few studies have focused on investigating delays in rural road construction projects in Iran. Therefore, the presented study aims to identify the causes of delay in rural road projects within Iran as well as prioritise the aforementioned causes based on their impacts on each other, since it is possible for one factor to increase the severity of other factors, thereby resulting in extended project delays. Furthermore, the findings generated from this research can help the road construction sub-sector develop a strategy that not only identifies the causes of delays but also highlights the interdependence of such factors, so that robust and sustainable mitigations are implemented at incipient stages

Literature Review

Given the significance of delays and cost overruns in projects, numerous studies have been conducted to identify their causes and effects. A detailed investigation into the Woliso–Ambo Road construction project indicated that rising material costs, equipment security, and shortcomings in project management were the major contributors to schedule delays, accounting for nearly 79% of the variation in project duration (Kalkidan Kefale Berta & Mesfin Tesfaye,2025). (Assaf & Al-Hejji, 2006) mentioned that time and cost overruns occur when a project is not completed according to the predefined plan within the contract. A study by Menesi (2007) further expanded the concept of project delays, classifying them into three groups based on their liabilities. The three identified groups are excusable delays (further segregated into compensable (owner) and non-compensable), inexcusable delays, and concurrent delays (Menesi, 2007). Similarly, Odeh and Battaineh (2002) identified the most critical reasons for delays affecting construction projects, as reported by contractors and consultants in Jordan. Their study specified that "owner interference", "inadequate contractor experience", "financing and payments", "labour productivity", "slow decision-making, "improper planning", and "subcontractors" were the seven most vital factors. Moreover, "Labor productivity" was introduced as the most important cause of delay. Gunduz et al. (2015) assessed the causes of delays and proposed a decision-support method for contractors prior to a contract. They classified 83 delay factors using a combination of the relative importance index (RII) and fuzzy logic, based on qualitative data collected from experts through interviews, after which the identified causes were ranked according to their impact on project delays. An integrated approach using questionnaire surveys and case studies identified security challenges, corruption, quantity variations, inadequate feasibility analysis, and adverse weather as primary causes of time delays and cost overruns in construction projects in Afghanistan (Hafizullah Sadat & Nivea Thomas, 2024). Furthermore, a study by Fallahnejad (2013) examined the implications of "work-related injuries", "importation of materials", "unrealistic project duration", "client-related materials", "expropriation", "change of orders", "contractor selection methods", "payment to contractors", "work permit processes", and "suppliers/contractors' cash flow" on project delays. The study revealed that although deviations from the initially set targets for any of the aforementioned factors could have severe consequences for project delays, "work permit processes" and "suppliers/contractors' cash flow" were the most impactful. Through a detailed review of secondary data, Habibi et al. (2018) also claimed that the most common cause of delay and cost overrun at the engineering and construction phases of projects is "design change". The findings of other similar reviews on the causes of project delays are presented in Table 1.

Table 1. Summary of review studies on causes of project delays

Paper	Author	Year	Indicated causes
Delay in Construction of Highway and Expressway Projects(Kumar, 2020)	Vijay Kumar	2020	Political situation.
			Awarding projects to the lowest bidders.
			Unable to hand over the required free Right of Way (ROW) on time to the Client.
			The Client delays progress payments.
			Insufficient & incompetent workforce engagement
	Pornsirichotirat Thapanont	2018	Incomplete project data and specification

Paper	Author	Year	Indicated causes
Causes of delay on highway construction projects in Thailand(Thapanont et al., 2018)			Insufficient workforce experience Poor equipment reliability or the financial status of contractors Delay in relieving environmental impact Shortage of materials Delay in relocating existing utility structures Lack of traffic safety management during construction Poor site management
Factors Influencing the Delay of Road Construction Projects in Northern Mindanao, Philippines	Ruel R. Cabahug*, Mariell B. Arquita, Sheena Marie E. De La Torre, Michelle S. Valledor and Shiela Mae D. Olivares	2018	change in quantity peace and order heavy Rain
Identifying Factors Causing Delays and Cost Overruns in Construction Projects in Colombia(Lozano Serna et al., 2018)	Sara Lozano Serna1, Ivonne Patiño Galindo2, Adriana Gómez-Cabrera3 y Andrés Torres4	2018	inadequate planning lack of integration among professionals
Study of factors influencing construction delays in rural areas in Malaysia(Ramli et al., 2018)	M Z Ramli, M A Malek, M H Hanipah, C L Lin, M F Mahamad Sukri, M H Zawawi, M Z Zainal Abidin, and N F S Mohamad Fuad	2018	Improper construction method implemented by the contractor. Weather conditions (wet Rain) Difficulties in making deliveries to the site. Poor qualification of contractor technical staff Breakdown of critical equipment
Delay in construction projects: a review of causes, need and scope for future research(Venkatesh & Venkatesan, 2019)	Prasad Kudrekodlu Venkatesh and Vasugi Venkatesan	2017	delays in payments from the Client deficiencies in planning & scheduling Delays and inaccuracies in technical information, such as drawings change of orders
Causes of Delays During Construction Phase of Road Projects due to the Failures of Contractor, Consultant, and Employer in Addis Ababa City Road Authority (Amare, Quezon, & Yesuf, 2017; Amare, Quezon, & Busier, 2017)	(Amare, Quezon, & Busier, 2017)	2017	Poor project finance control and monitoring process Difficulties in financing the project by the contractor Over-prioritisation of the lowest bid over quality Poor site management and supervision of the contractor Selection of inappropriate contractors

Paper	Author	Year	Indicated causes
			Poor project task scheduling by the contractor
			Inaccurate initial project scope estimate
			Poorly trained contract staff, especially in construction management techniques
A Management Framework to Reduce Delays in Road Construction Projects in Sudan(Khair et al., 2018)	Khalid Khair, Zainai Mohamed, R. Mohammad, Hazir Farouk, and Mohammed Elhadi Ahmed	2017	Poor cash flow
			Delays in payment to the contractor
			Project financing challenges
			Unstable economic climate, especially the effects of inflation on the prices of materials
			financial conflicts between the contractor and his subcontractor
			financial conflicts between the contractors and their workers
Schedule Delay in Saudi Arabia Road Construction Projects: Size, Estimate, Determinants and Effects(Mahamid, 2017)	Ibrahim Mahamid	2017	Poor project planning
			poor labor productivity
			Changing task lists due to emergent tasks
			Rework and lack of contractor experience
Causes of Construction Delays in Qatar Construction Projects(Gunduz, 2016)	Gunduz, M.; Abu Hassan, M.H.A.	2016	Delays in decision-making
			Poor site management Shortage of construction materials
			Changes to project scope by Client
			Human resources shortage
Analysing Delays of Road Construction Projects in Cambodia: Causes and Effects(Santoso & Soeng, 2016)	Djoen San Santoso, Ph.D., and Sothy Soeng	2016	Poor weather conditions, especially Rain and wind
			Awarding the project to the lowest bidder
			Poor equipment reliability due to frequent breakdowns
			Poor site arrangement, management, and supervision
			poor ground conditions and terrain
			Unqualified contractor technical staff and project teams
			late progress payment
			low staffing productivity

The critical role of rural road infrastructure in the economic advancement of nations cannot be over-emphasised, as it links urban cities, which often serve as administrative capitals and sources of most manufacturing raw materials and agricultural products, thereby boosting gross domestic product (Agumba, 2016). Despite the somewhat obvious significance of developing seamless transportation networks, infrastructure projects in the rural areas of developing nations are often plagued by delays and cost overruns, yet this is not adequately reflected in the classes of studies available in the literature. To address some of the research gaps in the underrepresentation of studies on delays in rural projects, this study initially examines the most common causes of delays in rural road construction projects using Iran as a case study, after which a ranking regime was implemented based on meticulously developed criteria.

Research Methodology

This study employed both survey and statistical analyses to probe the causes of delays in rural road construction projects. The research methodology for this study comprises three main stages. In the first stage, 100 delayed projects were identified using secondary data from the General Ministry of Roads and Urban Development of Fars province (Iran). Then, a set of questionnaires was used to identify the leading causes of delays in the identified projects. A combination of 10 experts from the General Ministry of Roads and Urban Development of Fars province and 30 contractors who were responsible for those projects were recruited as participants during primary data collection. Details about the age, educational background, and experience levels of the participants are provided in Tables 2 and 3 for better visualisation. The questionnaire included 30 leading causes of delay identified in the existing literature, and participants were asked to indicate the causes they experienced. Then, the 10 most important causes were selected. In the second stage, the DEMATEL (decision-making trial and evaluation laboratory) method was used to identify each factor's impact. This method has proven very effective for identifying the cause-and-effect chain components of a complex system (Ji et al., 2018). During this stage, a purpose-designed DEMATEL questionnaire was deployed to the same groups of experts and contractors. Finally, the identified causes were ranked using the ANP (Analytic Hierarchy Process) method. In this step, the data from the DEMATEL matrix were converted into a prioritisation matrix using ANP, as depicted in Figure 1

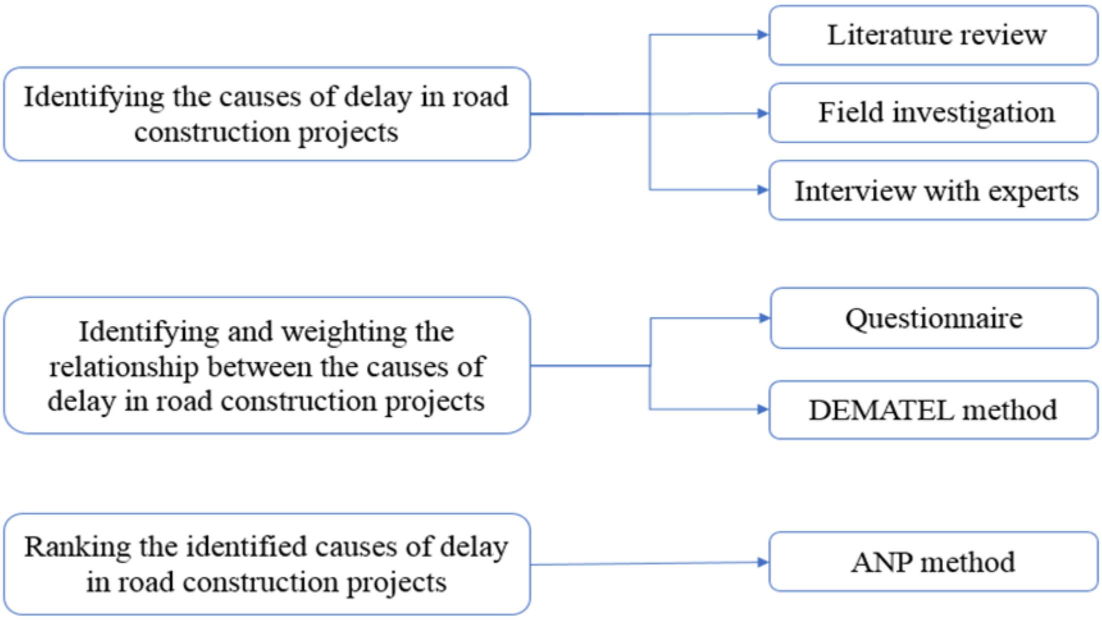

Fig 1. Research Methodology

Table 2. Information about experts

Category	Classification	Number	Frequency Percentage
Age	Younger than 25 years old	1	10%
	Between 26 and 35 years old	2	20%
	Between 36 and 45 years old	3	30%
	Between 46 and 55 years old	2	20%
	Older than 56 years old	2	20%
Educational level	Bachelor	1	10%
	Master	4	40%
	PhD	5	50%
Experience	Less than 5 years	1	10%
	6-10 years	1	10%
	11-15 years	2	20%
	16-20 years	6	60%

Table 3. Information about contractors

Category	Classification	Number	Frequency Percentage
Age	Younger than 25 years old	1	3.3%
	Between 26 and 35 years old	1	3.3%
	Between 36 and 45 years old	8	26.7%
	Between 46 and 55 years old	12	40%
	Older than 56 years old	8	26.7%
Educational level	Bachelor	5	16.7%
	Master	16	53.3%
	PhD	9	30%
Experience	Less than 5 years	3	10%
	6-10 years	9	30%
	11-15 years	13	43.3%
	16-20 years	5	16.7%

DEMATEL Method

The DEMATEL technique was introduced in 1972 (Fontela & Gabus, 1974) as a decision-making method that also involves pairwise comparison, based on the extraction of information related to crucial factors about a system from experts, which in turn provides a hierarchical structure of the system's factors, aids the examination of the level of influence that individual factors have on each other. One of the advantages of the DEMATEL method over other pairwise comparison-based decision-making methods is its acceptance of feedback on relationships. In the resulting hierarchical structure, each element can affect all elements at the same level, higher levels, or lower levels. In other words, the role of experts throughout the implementation of this technique is crucial. Key factors will be clarified using the direct influence matrix, after which the priorities of each factor will be specified. While the elements within the system may not be independent of each other, the importance and weight of each factor in the system are ultimately determined by not only upstream factors or exclusively downstream factors but also by all factors in the system, or, in other words, the whole model (Si et al., 2018). Although there are many methods to determine the importance of relationships between factors, some of the most widely applied approaches involve seeking the opinions of experts who are very familiar with how the internal and external factors generated in theory affect organisations in practice. Hence, the DIMATEL approach is implemented to identify the most common causes of delays based on data from the returned questionnaires. The results of the technique will be extracted as effective and influential factors. As earlier highlighted, the aim of adopting the DEMATEL technique is to identify the causal relationships (including their corresponding strengths) between the different delay factors. The implementation of the DEMATEL technique involves various steps as presented below:

Step 1: Creating the average matrix based on the expert opinion (matrix Z)

To assess the relationship between n criteria and l experts, the comparison scale was determined as 0-4, whereby 0 and 4 illustrate 'no influence' and 'powerful influence', respectively. The influence matrix of the lth respondent between total factor n is given as:

$$\boldsymbol{Z}^{\mathbf{h}} = \left[Z_{ij}^{l}\right] n * n \qquad (1)$$

In order to determine the value of influencing each factor from all defendants, considering the score from the criteria $\boldsymbol{a_i}$ to $\boldsymbol{a_j}$ Is given as:

$$Z_{ij} = \frac{\sum_{l=1}^{L} Z_{ij}^{l}}{L} \qquad (2)$$

Step 2: calculating the normalized initial direct-relation matrix (matrix $\boldsymbol{X}$)

The normalized initial direct-relation matrix is achieved by normalizing the average matrix $\boldsymbol{Z}$, by dividing matrix $\boldsymbol{Z}$ by $\boldsymbol{s}$.

$$s = max\left[max_{1\,"i"\,n} \sum_{j=1}^{l} z_{ij}\,, max_{1\,"i"\,n} \sum_{i=1}^{l}\right] \qquad (3)$$

Step 3: calculating the total influence matrix (matrix T)

In this step, to realize which factor has the most significant direct and indirect influence on the other factor, and to indicate the most influential and compelling factors, matrices l and T are multiplied. Matrix T, the total relation, is obtained using Equation (4):

$$T = N(I - N)^{-1} \qquad (4)$$

Step 4: Obtain the impact-relations map (IRM)

In this step, the corresponding R and D values are calculated as follows:

$$D_i = \sum_{i=1}^{n} t_{ij} \qquad (i = 1, 2, \ldots\ldots, n) \qquad (5)$$

$$R_j = \sum_{j=1}^{n} t_{ij} \qquad (j = 1, 2, \ldots\ldots, n) \qquad (6)$$

Where t_{ij} Is the (i, j) element of Matrix T.

Then, $(D + R)$ and $(D - R)$ values are calculated in order to measure the level of the influence of factors. $(D + R)$ The value is called "prominence", which indicates whether the factor is influencing or being influenced. However, $(D - R)$ value is known as "relation", which shows the effectiveness of the factor; if it is positive, the factor is a "cause factor", and if it is negative, the factor is influenced by other factors.

Step 5: Set a threshold value and draw the cause-and-effect diagram

In order to explain the structural relation between the factors, it is necessary to set a threshold value p to filter out the irrelevant effects in matrix T. The threshold value is deduced by calculating the average of all the elements in matrix T. Then, the matrix T is divided into "p". Comparing the obtained matrix to matrix T, if the element in matrix T is less than p, it would be considered 0, and if it is higher, it would be considered 1. Thus, 0 indicates no relationship in the obtained matrix, while 1 indicates a relationship.

ANP Method

Saaty pioneered the Analytical Hierarchy Process (AHP) to solve complex decision-making problems (Saaty & Vargas, 2006). The ANP is another decision-making technique, similar to the Analytical Hierarchy Process (AHP) method. The ANP method is a generalization of the AHP method, owing to the AHP method's inability to handle problems that involve lower levels exerting influence on higher levels or in which the elements within a level are not independent. Therefore, this study used the ANP technique, as it can show more complex relationships across different levels of decision networks and considers interactions and feedback between criteria and alternatives.

ANP implementation typically proceeds in two steps, with the first a linear hierarchy of network relations among the goal, criteria, and sub-criteria. The second step is the feedback network, which contains the network relation between clusters and elements. Independencies are produced, and the network relation of the

ANP approach then calculates the weights of the criteria. This stage forms a supermatrix used to eventually determine the values of the weights for criteria and alternatives. Further details on the theory and implementation of the ANP process for solving construction problems are available in earlier studies, including Balali et al. (2021); Brožová & Růžička (2010); Hasnain et al. (2018); Hatefi & Tamošaitienė (2019); and Valipour et al. (. In this study, ANP was used to rank the causes of delays in road construction projects, as the DEMATEL technique only identifies causal relationships. The outputs of DEMATEL were transferred to ANP to determine and prioritize the leading causes of delays.

Research findings

Identification of delay causes

The identified results are shown in Table 4 and explained as follows:

A- Lack of credits: lack of credits incorporates the lack of timely provision of project funds, failure to make prepayments, and the uncertainty of payment strategies with contractors and suppliers.

B- Political challenges: The most prevalent political challenge with rural projects arises when one government abandons a project approved by a previous government due to political differences and misaligned strategies.

C- Shortage of skilled workforce: The shortage of skilled workers has significant detrimental effects on the productivity of project teams, which is further aggravated in rural areas due to their poor proximity to skilled worker pools and their concentration in urban areas.

D- Lack of materials/deficiency of materials: Typical construction processes entail converting conceptual designs into physical structures, and the realization of this hinges heavily on the availability of adequate construction materials (quality and quantity). Any shortage of such materials leads to project delays and, subsequently, disrupts workforce performance.

E- Land acquisition/conflicts: Land is a scarce natural resource, and its acquisition is considered one of the most crucial factors for construction projects. Major infrastructure projects, such as road construction, require significant land, and governments in most countries have clear laws that balance the public's need for infrastructure with the rights of landowners. Negotiating the release of such lands in the quantities required can take time and sometimes lead to prolonged conflicts among landowners, clients, contractors, and the government. It has been identified as a significant source of delays in project schedules.

F- Poor weather conditions: Climatic conditions are one of the main reasons for project delays. Climatic factors such as heavy rains, wind, and extreme heat can disrupt road construction projects and compromise the integrity of the resulting infrastructure.

G- Lack of necessary equipment: This has been recognized as a common cause of delays in infrastructure projects. Some of the reasons for this include inadequate review of equipment integrity before implementing the project or even during execution of the work.

H- Accuracy of design information: The fundamental means of communication between the project's design and execution teams is the technical specification, especially drawings. The alteration of such information without adequate change management procedures has led to immense delays, cost overruns, or even the abandonment of critical infrastructure projects.

I- Financial problems: Poor liquidity management, insufficient financial resources, instability of financial markets, and delays in payments by any of the stakeholders involved in the project life cycle can lead to cash freezes, which have contributed to the non-completion of projects within stipulated timeframes.

J: inflation: When a country experiences inflation, there is a general increase in the prices of all goods and services, which in turn leads to a corresponding decrease in the quantity and quality of goods that can be acquired with the same amount of money as previously. Infrastructure projects such as road construction sometimes last for years, making them susceptible to economic cycles and financial instability. It has become a common source of delays, cost overruns, and abandonment.

Table 4. Factors and their corresponding symbols

Factors	Symbols
Lack of credits	A
Political challenges	B
Lack of materials/deficiency of materials	D
Inflation	J
Lack of necessary equipment	G
Financial problems	I
Shortage of skilled human resources	C
Land acquisition/conflicts	E
Poor weather conditions	F
Accuracy of design information	H

Furthermore, a confirmatory factor analysis (CFA) approach based on the Camus-Bartlett test was used to estimate the loadings of the delay indicators for rural road construction projects, so as to determine the extent of delay variance. According to the CFA, the Camus-Bartlett test value was 28.357, which was significant at the 0.05 level. The variance matrix also depicts that the studied indicators explained 69.2% of the variance of delay in road construction projects. The normality tests and load factors for the different indicators are shown in Tables 4 and 5, respectively.

Table 4. The normality of the variables' test

Name		A	B	C	D	E	F
Normal Parameter	**Average**	7.3000	7.3000	7.0000	6.70	7.6000	6.2000
	Standard Deviation	1.15950	1.76698	1.88562	1.49	1.34990	1.13529
Difference Intensity	**Definite**	.227	.232	.202	.180	.217	.230
	Positive	.173	.169	.144	.120	.150	.170
	Negative	-.227	-.232	-.202	-.180	-.217	-.230
Kolmogorov-Smirnoff amount		.718	.734	.639	.568	.685	.728
Level of Significance		.681	.655	.809	.904	.737	.665
Name		**G**	**H**	**I**	**J**	**Economic-Social**	**Cost**
Normal Parameter	**Mean**	7.2000	6.8000	6.2000	7.00	6.9000	4.1400
	Standard Deviation	1.31656	.91894	.91894	1.05	.73786	.34059
Difference Intensity	**Definite**	.160	.286	.286	.229	.254	.170
	Positive	.160	.214	.286	.229	.246	.141
	Negative	-.140	-.286	-.214	-.171	-.254	-.170
Kolmogorov-Smirnoff amount		.507	.905	.905	.723	.803	.537
Level of Significance		.959	.386	.386	.673	.539	.935

Table 5. Load factor of the indicators

Symbols	factors	Load factor
A	Lack of credits	0.708
D	Lack of materials/deficiency of materials	0.748
J	Inflation	0.677
G	Lack of necessary equipment	0.706
I	Financial problems	0.880
C	Shortage of skilled workforce	0.623

Symbols	factors	Load factor
E	Land acquisition/conflicts	0.500
F	Poor weather conditions	0.778
H	Accuracy of design information	0.576
B	Political challenges	0.738

According to Table 5, the load factor for all indicators exceeds 0.5; therefore, they are desirable for measuring delay in rural road construction projects.

Identification and weighting of the relation between the factors causing delays

Section 3.1 has already provided the theoretical background of the DEMATEL method and its proficiency in determining the relationships among factors, as well as the effectiveness and impacts of the identified delay causes on each other. However, this section focuses more on describing how the DEMATEL method was practically implemented for this scenario. Earlier studies by Hu et al. 2009 showed that large sample sizes are not required to implement the DEMATEL. Method. Therefore, this study collected data from 10 experts involved in the management or regulation of delayed projects within the General Ministry of Roads and Urban Development of Fars province. The average matrix is derived by integrating the average scores assigned by experts, as shown in Table 5. For instance, Cause B has a high impact on Cause G, with an average of 3.1 on a 4-point scale. Based on the sums of rows and columns, we consider the highest value as the normalizing value (K = 30.8). Now we divide each of the above matrix elements by this value to obtain the normalized initial direct-relation matrix (Table 5).

Table 5. Calculate the sum of each row and column of the Average matrix based on the expert opinion

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**SUM**
A	0	1.5	2.4	2.1	3.5	2.3	2.6	3	3.6	3	24
B	3.4	0	2.1	2.9	1.7	2.2	3.1	2.7	3.6	2.7	24.4
C	3.1	2.4	0	2.4	2.5	2.9	3.2	3.1	3.2	3.3	26.1
D	2.9	3.7	3.1	0	2.6	2.7	3	3	3	2.4	26.4
E	3.6	3.6	3.1	2.8	0	3	3.4	2.9	3.7	2.4	28.5
F	3.2	3.8	2.5	3	3.6	0	3	2.1	3.6	2.2	27
G	3.4	2.9	3.1	2.6	2.7	3.5	0	3.1	3	3	27.3
H	3.4	3.9	2.7	3.2	3.1	2.4	4	0	2.9	3	28.6
I	3.1	3.8	3.2	3	3.9	3.1	3.2	3.4	0	1.4	28.1
J	3.8	3.8	2.8	3.8	3	3.6	3.1	3.2	3.7	0	30.8
SUM	29.9	29.4	25	25.8	26.6	25.7	28.6	26.5	30.3	23.4	

Equations (5) and (6) were used to identify the causes with the most or least interactions with other causes, to determine the cause that would serve as the most effective or most influential index. Then, calculate the sum of each row and each column. R represents the sum of the columns, which indicates the effect of one factor on all other factors, and D represents the sum of the rows, which represents the effect of all factors on one factor. In the next step, the values $(R + D)$ and $(R - D)$ are calculated, whereby the highest $(R + D)$ value indicates the index that has the most interactions with other indicators. On the contrary, the lowest $(R + D)$ value indicates the index that has the fewest interactions with other indicators.

Furthermore, the highest $(R - D)$ value indicates the most effective index, while the lowest $(R - D)$ value indicates the most influential index. According to Table 6, "financial problems" (I) has the most interactions with other causes, while "shortage of skilled manpower" (C) has the fewest interactions with other indicators. In addition, the most influential cause (based on its receiving the least influence from other factors) is "lack of credits" (A), while inflation (J) emerged as the least influential cause. The interaction and effectiveness of the factors are also presented in Table 7.

Table 6. The sum of the influences and impacts of factors on each other

Cause	R	D	R+D	R-D
A	6.5225	7.8951	14.4175	-1.3726
B	6.5525	7.7423	14.2948	-1.1898
C	7.0049	6.7087	13.7136	0.2962
D	7.0276	6.8762	13.9038	0.1513
E	7.5340	7.1197	14.6537	0.4142
F	7.1670	6.8604	14.0274	0.3066
G	7.2705	7.5813	14.8518	-0.3108
H	7.5714	7.0917	14.663	0.4797
I	7.4242	7.9984	15.4225	-0.5742
J	8.0988	6.2996	14.3984	1.7992

Table 7. Interaction and effectiveness of factors

Interaction	Factor	R+D	Effectiveness	Factor	R-D
I	Financial problems	15.4225	J	inflation	1.7992
G	Lack of necessary equipment	14.8518	H	Change in the original map	0.4797
H	Change in the original map	14.6630	E	Land Acquisition / Opponents	0.4142
E	Land Acquisition / Opponents	14.6537	F	Unfavourable weather conditions	0.3066
A	Lack of credits	14.4175	C	Lack of specialized people	0.2962
J	inflation	14.3984	D	Lack of materials/scarcity of materials	0.1513
B	political problems	14.2948	G	Lack of necessary equipment	-0.3108
F	Poor weather conditions	14.0274	I	Lack of funds provided	-0.5742
D	Lack of materials/scarcity of materials	13.9038	B	political problems	-1.1898
C	Lack of specialized people	13.7136	A	Lack of funds provided	-1.3726

Ranking of indicators with ANP

As described earlier, the DEMATEL technique only determines the intensity of relationships between indicators and causal relationships. Therefore, the ANP technique is used to rank the studied indicators. To implement this, the information in Table 10 was entered into the Super Decision3 software, and the incompatibility rate and indicator rank were determined. The outputs were then extracted using standard weights, as shown in Table 8.

Table 8. Ranking of indicators affecting delays in road construction projects

	A	B	C	D	E	F	G	H	I	J	Incompatibility rate	Normalized weight
A	1.0000	1.4903	1.6327	1.6205	1.4782	1.6080	1.4543	1.5165	1.3376	1.78	0.1 <0/02138	0.1433
B	0.6710	1.0000	1.6507	1.5603	1.5901	0.6206	0.7030	0.6538	0.7501	0.59		0.0908
C	0.6125	0.6058	1.0000	1.5013	0.6906	0.6786	1.3362	0.7038	0.7842	0.6407		0.0796
D	0.6171	0.6409	0.6661	1.0000	0.6934	0.6739	1.3421	1.4231	0.7810	0.6180		0.0794
E	0.6765	0.6289	1.4480	1.4422	1.0000	1.3793	1.2455	1.3434	0.8498	0.6568		0.0992
F	0.6219	1.6113	1.4736	1.4839	0.7250	1.0000	1.3200	1.4484	0.8115	0.6220		0.1019

	A	B	C	D	E	F	G	H	I	J	Incompatibility rate	Normalized weight
G	0.6876	1.4225	0.7484	0.7451	0.8029	0.7576	1.0000	1.3767	0.8053	0.6531		0.0852
H	0.6594	1.5295	1.4209	0.7027	0.7444	0.6904	0.7264	1.0000	1.2019	0.6770		0.0881
I	0.7476	1.3332	1.2752	1.2804	1.1767	1.2323	1.2418	0.8320	1.0000	0.6215		0.1006
J	0.5621	1.6989	1.5608	1.6181	1.5225	1.6077	1.5312	1.4771	1.6090	1.0000		0.1319

Based on the ranking of the indicators that affect delays provided in Table 8, a prioritization scheme was created in Table 9, where it can be seen that lack of credits (A) is the leading cause of delays in rural road construction, while the accuracy of design information exerted the least effect on the time extension of rural road projects

Table 9. Ranking of delay indicators in road construction projects

Symbols	Factors	Normalized weight	Priority
A	Lack of credits	0.1423	1st
J	Inflation	0.1319	2nd
F	Poor weather conditions	0.1019	3rd
I	Financial problems	0.1006	4th
E	Land Acquisition / Opponents	0.0992	5th
B	Political problems	0.0908	6th
H	Revising the drawings	0.0881	7th
G	Lack of materials/scarcity of materials	0.0852	8th
C	Lack of specialized people	0.0796	9th
D	Lack of necessary equipment	0.0794	10th

Several earlier studies have discussed delays and their effects on road construction projects, but very few were actually focused on rural road projects. On the rare occasions when studies investigated delays in rural road construction projects, the identified delay causes were often individualised, without prioritising them based on the impacts they exerted on one another. In this study, however, the most prevalent cause of delays in rural road projects was initially identified as lack of funds, after which it was determined that "financial problems" had the most interactions with other factors. The resources (including workforce, money, materials, methods, and machines) available to organisations are often limited, thereby leading to the selection of the most critical challenges to address at every given time. However, a precursor to the implementation of solutions for Critical problems are prioritization. Therefore, in addition to identifying the most prevalent causes of delays in rural projects, the outcomes of this study would enable decision-makers within organisations to adequately identify the most influential factors, so as to focus efforts where they are most needed.

Results

This study analyses the leading causes of rural road project delays and their criticalities. The study initially identified the extent of interactions among individual factors. The results of the study depict the following financial problems: lack of necessary equipment; accuracy of design information; land acquisition/conflicts; lack of budget; inflation; political challenges; poor weather conditions; lack of materials/deficiency of materials; and shortage of skilled staffing, which had the most significant interactions with other factors. Furthermore, the DEMATEL approach was used to ascertain the level of influence that factors exerted on each other where it was revealed that inflation, accuracy of design information, land acquisition/conflicts, poor weather conditions, shortage of skilled workforce, lack of materials/deficiency of materials, lack of necessary equipment, financial problems, political challenges, and lack of budget were the most influential. The next purpose of this study was to prioritize indicators in terms of their importance in causing delays in rural road projects. The ANP technique was used due to its ability to handle such problems. Consequently, the following were obtained as the priorities: Lack of credits; Inflation; Inappropriate air and climate; Financial problems; Land acquisition/conflict; Political problems; Change in baseline map; Lack of equipment; Specialist shortage; Lack of materials/scarcity of materials. Despite the outcomes reported in this study helping rural road project stakeholders mitigate delays at the incipient stage, the approach adopted is considered limited, as it considers only 10 leading causes of delays in rural road construction project activities. Therefore, to enhance the generalizability of the approach and the findings reported here, it is suggested that future research endeavours replicate the approach using data from a wider range of projects, of varying magnitudes and across different industries, to determine and quantify commonalities and variations adequately.

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