Artículo de investigación

A Mathematical Programming Model to Identification and Reduce the Cause of Project Delays by using Gray Multimoora Method

Un modelo de programación matemática para identificar y reducir la causa de los retrasos del proyecto utilizando el método de Gray Multimoora

Um Modelo de Programação Matemática para Identificação e Redução da Causa de Atrasos no Projeto Usando o Método Multimoora Cinza

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Abstract

A distinctive problem related to projects is the delay in the process of executing them. In general, delays are due to different factors which are originated from the individuals who are concerned with the projects. This problem is more important in megaprojects because of their complexity, uncertainty and long execution time. If the causes of delays are identified at the beginning of their execution, they can be prevented or reduced through appropriate activities. Changes in any factors of the project such as human forces, constructing material and other resources may cause delays in timing the projects. This is an applied research in which theoretical data were collected using the library method. Interviews and questionnaires distributed among the experts of this field were the tools of collecting data. Through a short review on delays in projects, 10 common effective reasons were found which were related to the employer, contractor and the consultant. This study was conducted and weighed on the projects of local electricity power companies in Fars province. Using the three aspects of Gray MULTIMOORA, a model was designed to prioritize the factors that cause the delay. This study suggests some solutions to control and reduce the delays.

Resumen

Un problema distintivo relacionado con los proyectos es el retraso en el proceso de ejecución. En general, los retrasos se deben a diferentes factores que se originan en las personas que están preocupadas con los proyectos. Este problema es más importante en los megaproyectos debido a su complejidad, incertidumbre y largo tiempo de ejecución. Si las causas de los retrasos se identifican al comienzo de su ejecución, se pueden prevenir o reducir mediante actividades apropiadas. Los cambios en cualquier factor del proyecto, como las fuerzas humanas, la construcción de materiales y otros recursos pueden causar retrasos en el cronograma de los proyectos. Esta es una investigación aplicada en la que los datos teóricos se recopilaron utilizando el método de la biblioteca. Las entrevistas y los cuestionarios distribuidos entre los expertos de este campo fueron las herramientas de recolección de datos. A través de una breve revisión de los retrasos en los proyectos, se encontraron 10 razones efectivas comunes relacionadas con el empleador, el contratista y el consultor. Este estudio se realizó y pesó sobre los proyectos de las compañías eléctricas locales en la provincia de Fars. Utilizando los tres aspectos de Gray MULTIMOORA, se diseñó un modelo para priorizar los factores que causan el retraso. Este

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estudio sugiere algunas soluciones para controlar y reducir los retrasos.

Palabras claves: Modelo, retraso, proyecto, gris MULTIMOORA.

Resumo

Um problema distinto relacionado aos projetos é o atraso no processo de execução. Em geral, os atrasos são devidos a diferentes fatores que são originados dos indivíduos que estão preocupados com os projetos. Este problema é mais importante em megaprojetos devido à sua complexidade, incerteza e longo tempo de execução. Se as causas de atrasos forem identificadas no início de sua execução, elas podem ser evitadas ou reduzidas por meio de atividades apropriadas. Mudanças em quaisquer fatores do projeto, tais como forças humanas, construção de material e outros recursos podem causar atrasos no cronograma dos projetos. Esta é uma pesquisa aplicada em que dados teóricos foram coletados usando o método de biblioteca. Entrevistas e questionários distribuídos entre os especialistas deste campo foram as ferramentas de coleta de dados. Através de uma breve revisão sobre os atrasos nos projetos, foram encontrados 10 motivos efetivos comuns relacionados ao empregador, ao contratado e ao consultor. Este estudo foi conduzido e pesado sobre os projetos de empresas locais de energia elétrica na província de Fars. Usando os três aspectos do MULTIMOORA Cinza, um modelo foi projetado para priorizar os fatores que causam o atraso. Este estudo sugere algumas soluções para controlar e reduzir os atrasos.

Palavras-chave: Modelo, atraso, projeto, cinza MULTIMOORA.

Introduction

A common problem in civil project is the delay in executing and exploiting them. Generally speaking, one of the main factors of a successful evaluation of a project is executing it in the determined time so that there is no delay in completing the project. Environmental changes are dynamic indices of projects which happen a lot when executing a project. In comparison with other factors, achieving time goals is the most important index of the success of a project. One of the distinctive problems of executing a project is the delay in executing it (Terohid, 2004). Delay is a phenomenon that prolongs the time schedule of a contract. In another word, delay is an interval between the designed and real-time of executing a project. In general, delays are due to different reasons which are originated from the performance of the groups involved in the project (Hajivand et al, 2011). Delay is a threat for the beneficiaries of a project, both the government and the people. The most important and expensive loss which is originated from the delay is the waste of time. This in turn, increases the costs, causes the dissatisfaction of the citizens, makes the urban environment unpleasant and creates traffic problems. Delay in huge civil projects such as those of the local electricity power company in Fars province. In these projects, the electricity power company constructs transferring and distributing electricity lines and power plants.

As it was mentioned, any delay has different effects on the project. For instance, it prolongs the time of completing the project, increases the direct and indirect costs, prevents from achieving the predetermined goals and wastes the time. These problems can make disputes between the beneficiaries of the project and they may make a claim. Sometimes the delay may result in legal trials. All these consequences take a lot of time, cost, and energy. Thus, it is necessary to develop appropriate processes and methods to identify and analyze the delay, its causes and the way of managing it.

All managers want to reduce the losses of the project. Despite detailed timing at the beginning of the project, using high technologies and project managing techniques, usually, the average of time and cost losses are significantly higher than the predicted programs. It is worth mentioning that despite all developments, executing more projects and consequently being more experienced, logically the delays and the time of executing projects should be reduced while to some extent it is not possible. In most projects, using trial and error method and the

acquired experiences and knowledge wastes a large amount of national capital. So experiences can be a solution both for the existing problems and those of the future projects. Knowledge and experience resulted from solving the problems such as delay in executing the projects is a type of tacit knowledge which mostly is in the mind of those who are involved with the project and may never be used once more when these people leave the project. If these documented knowledge and experiences are shared and re-used, they can optimize the process of executing the project, reduce the time and cost and prevent the similar problems (Zarabadi, 2007).

With a little attention to the different and common factors which are considered as the reasons of delay in projects, it will be understood that nearly the majority of the mentioned factors are due to the weakness of the planning system. If the project is divided into three initial, middle and final period then it can be said that delays and problems such as the lack of clarity in the contract, designing based on incorrect information or delay in receiving the designing information have many effects on the time of executing the project. For many reasons, this problem can be originated from planning and designing processes. One reason for this weakness is that the planners set the plans with an ideal approach while when executing the project, they face the real world (Tusi et al., 2008).

Literature review of the studies conducted on delay

So far different studies have been conducted on delay some of which aim to convert these delays into quantitative values and using different methods, the researchers studied this issue (Schumacher, 1995). The other researchers studied the delay in the industry of a certain country. Among these researches one can point to "The reasons of delay and the increase of costs in construction projects in Nigeria (Mansfield et al., 1995)", "Identifying the reasons of delay in construction industry of Lebanon (Mezher et al., 2012)" and "The factors affecting the delay in airport projects of Iran (Ghotbi, 2008)". The carried out studies showed that during the previous years, in different projects i.e. from the simple construction projects to the most complicated ones such as petrochemical, dam construction, and nuclear power plant projects delay has occurred. Delays in projects cause more use of the resources, the reduction of profit or the loss of opportunities. So, considering the limitation of the existing resources and the strong compatible market, today in most developed and developing countries, they are trying to better use of resources and gain more profit. Thus, in these countries, the researchers try to find the original causes of delay in previous projects and introduce appropriate solutions for reducing the delay in future projects. According to the studies carried out between 1993 and 2010, in the past, the researchers did not show significant efforts to identify the reasons of delay while from 2002 in some developing countries such as Indonesia, Saudi Arabia, Vietnam, United Arab Emirates, Malaysia, Jordon and Zambia, this issue had great importance (Barzinpour and Pirouzfar, 2010).

Table 1 shows more information about the time and cost of executing the projects in the United States. The information shows that in most countries, the time and cost of projects have been increased (Parchami and Hosseini, 2016).

Table 1 Cost information and predicting the time of completing some projects in the U.S.A

The project	Cost (dollar) and predicting the time of completing the project	Final cost (dollar) and the year of completing the project
Boston urban underground tunnel	6.2 billion (1985)	6.14 billion (2002)
Denver international airport	7.1 billion (1989)	8.4 billion (1995)
Virginia urban highway bridges	241 million (1994)	676 million (2003)
Seattle urban light train	7.1 billion (1996)	6.2 billion (2000)

The considerable point is that according to the report of Plan and Budget Organization, in %90 of civil projects, the time and cost have been increased during the above-mentioned period. Furthermore, %60 of semi-completed projects would be completed 15 years later (Shakeri and Ghorbani, 2015). It is worth mentioning that, at present the average time of completing civil projects in Iran is about 9 years which is too different from the standard time-table (Shakeri and Ghorbani, 2005). Yaghoubzade et al. (2015) studied the delay of executing the projects in terms of project factors. They used questionnaires to determine the reasons of delay in completing the projects. They identified three main reasons which are the delay in payment to the contractor, lack of providing enough budgets for the project and the contractor's insufficient financial resources. In another research, the reasons of delay in urban civil projects were studied. In that research, the case study was the overpass bridge in Gorgan city. According to statistical calculations, using SPSS software and Duncan and Fisher's test, the researchers showed that among some selected factors, the contractor, the employer and the consultant who are considered as the agents of the project, had the most effect on the delay in projects while the law and regulation has the least effect (Yaghoubzade and Aghil, 2015). In another research, the causes of delay and the time performance in civil projects were studied. In that research, two construction projects were presented as samples. The results showed that lack of correct planning can cause the most losses to the time performance of a project (Gonzalez et al., 2013). In a similar research, the causes of delay in executing the civil projects were analyzed. The results showed that factors such as shortage of budget, changes in the design, lack of strong communication and the weak points of the project manager are the most reasons of delay in executing the projects (Samia and Pranay, 2013). In another research, the factors that cause delay in civil projects of Turkey were introduced. The results showed that the delay in payment is the main reason that affects the prolonged projects (Casas et al., 2012).

After studying different researches, now it can be concluded that the main agents of the project (the employer, the contractor and the consultant) are important causes of delay in projects. Thus, it is necessary that through systemizing the project management and creating a technical approach towards project management at the macro level, these agents try to reduce the delay in the projects.

To prioritize the project agents (the employer, contractor and consultant), Gray MULTIMOORA was used since due to the uncertain nature of the data related to evaluation indices, deciding about prioritizing is based on fuzzy or gray logic. Hence, as fuzzy logic requires the extract of membership function, and choosing the factors which are involved in the project faces the problem of insufficient number of the experts and their insignificant experience which is less than 10 years, using gray logic is more logical than using fuzzy logic. MOORA method in newer than the other methods and in comparison with other decision making methods which are affected by the weights and normalization, gives much more constant results. Some relations between two gray numbers which have many applications are as below:

Equation 1:

$$\otimes_1 \epsilon [a, b], \otimes_2 \epsilon [c,d]$$

Equation 2:

$$\otimes_1 + \otimes_2 = [a + b, c + d]$$

Equation 3:

$$\otimes_1 - \otimes_2 = \otimes_1 + (- \otimes_2)$$

Equation 4:

$$\otimes_1 * \otimes_2 = [\min\{ac,ad,bc,bd\}, \max\{ac,ad,bc,bd\}]$$

Equation 5:

$$\otimes_1 / \otimes_2 = [\min\{a/c,a/d,b/c,b/d\}, \max\{a/c,a/d,b/c,b/d\}]; cd>0$$

Equation 6:

$$K \times \otimes_1 \epsilon [ka,kb] ; k \epsilon R^+$$

Equation7:

$$K \times \otimes_1 \epsilon [-ka,-kb] ; k \epsilon R^-$$

White value (certain)

The white value of a gray number range ($X\otimes$) is a certain number which has a false value between the upper and lower limits of gray range of the number X. The white value (real) of a gray number data ($X\otimes$) can be shown as below (Kim, Jung, Leo and Shung, 2012).

Equation8:

$$X() = \lambda \underline{xij} + (1- \lambda) \ \overline{xij}$$

The history of using MOORA method

In 2014, Attri and Gruber used MOORA method for decision making along the active cycle of the production system. In 2013, Gorener, et al. used MOORA to choose the most appropriate place for establishing a branch of a bank. In 2012, Karande and Chakraborty used MOORA method to choose the material. In 2012, Stanujkic et al. developed MOORA method to use periodic data. In 2010, Gadakh used MOORA to parametrically optimize the process of turning. In 2009, Zavadskas and Brauers, and Brauers et al. (2008) used MOORA method to assess the contractors in facility section. Ginobius and Brauers (2009) used MOORA method to define economic policies for local balanced development in Lithuania (Steve King et al., 2011).

The necessity of the research

Studying the different existing resources showed that there are diverse reasons for the delay in executing the projects. So, to classify these reasons is important as they are common between the agents of the project (the employer, contractor, and consultant). Through weighing the reasons of delay, a model is introduced to prioritize the reasons in the regional electricity power company in Fars province. This model is based on Gray MULTIMOORA and is used to reduce and manage the delays.

The main and sub-goals of the research

The main goal of the research is to introduce an efficient model to prioritize the causes of delay and give weight to common causes. Thus, to achieve the main goal, the following sub-goals are considered:

1. Identifying the causes of delay which are common to the employer, contractor and the consultant.
2. Determining the level of importance or the weight of the causes through Gray Shannon's entropy method.
3. Prioritizing the causes of delay using Gray MOORA method.
4. Comparing the achieved results with the previous performance of the company.

The main and sub-questions of the research

1. Which causes of delay are common between the employer, contractor, and consultant?
2. How important is each identified cause of delay?
3. What is the priority of the causes of delay (employer, contractor, and consultant) in the robots of the production line based on Gray MULTIMOORA?

Methodology

As the aim of this research is to introduce a model to identify the causes of delay which are common in the agents of the project and to reduce them, it is a practical study. To collect data about the theoretical bases of the research, library resources were used. In terms of the analyzing method, this study is a multi index decision making which prioritizes the causes of delay (the employer, contractor, and consultant) using three "ratio system", "complete multiplication" and "reference point" attitudes. The first two attitudes are compensation while the third one in non-compensation.

The statistical community, sample and sampling method

The statistical community of this research is all the experts related to the projects of the regional electricity power company of Fars province including all managers, contractors, and consultants who are estimated to be 130 people. The sampling method is non-random and available strategy using which, 26 experts were selected. All the experts are the managers whose course of study is related to the subject of the research and have a maximum of 10 years experience in this field.

To form a theoretical framework for this research, articles, books, the related theses and valid scientific websites were used. To collect data required for the input of the decision-making model, questionnaires were used. A questionnaire is reliable and valid when it is appropriate to evaluate the subject of the research. This type of questionnaire was distributed among the experts and its reliability

was confirmed. The reliability of the questionnaire refers to its preciseness. When a questionnaire is distributed among a group of responders for several times and with short time intervals and the results are nearly the same, then it is valid.

The general steps of conducting the research

The first step: In this step, the causes of delay which are common among the employer, contractor, and consultant are identified. All these causes are considered as indices and were identified through library studies and interviews with the experts.

The second step: Designing the questionnaires based on the identified causes of the delay and distributing them among the experts and receiving their views on the effect of each agent of the project (the employer, contractor, and consultant) on the delay and turning the qualitative responses to the corresponding gray numbers.

Table 1 Measuring scale in gray numbers literature

Measuring scale	The gray number
Too little	[0 1]
Very little	[1 3]
Little	[3 4]
Mean	[4 5]
Much	[5 6]
Very much	[6 9]
Too much	[9 10]

The third step: Gray scale averaging the responses and forming the decision-making matrix of the average responses.

The fourth step: Normalizing the gray decision-making matrix using the simple normalizing equation based on equation (9):

Equation (9):

$$X^{*}_{ij} = \frac{\overline{Xij}}{\sum_{i=1}^{n} \overline{xij}}$$

$$X^{*}_{ij} = \frac{\underline{xij}}{\sum_{i=1}^{n} \underline{xij}}$$

The fifth step: Calculating the weight of the causes of the delay using gray entropy weighting method based on equations 14 to 20 (Kim Jung Leo).

Equation (14):

$$\overline{Ei} = \frac{1}{lnp} \sum_{j=1}^{m} \overline{xij} \text{ LN } \overline{xij}$$

Equation (15):

$$\underline{Ei} = \frac{1}{lnp} \sum_{j=1}^{m} \underline{xij} \text{ LN } \underline{xij}$$

Equation (16):

$$\overline{Di} = 1 - \overline{E}$$

Equation (17):

$$\underline{Di} = 1 - \underline{xij}$$

Equation (18):

$$\overline{Wi} = \frac{\overline{D}}{\sum_{i=1}^{n} \overline{D}}$$

Equation (19):

$$\underline{Wi} = \frac{\underline{D}}{\sum_{i=1}^{n} \underline{D}}$$

Equation (20):

$$W_i = [\overline{wi}\ \underline{wi}\ ]$$

The sixth step: Using the attitude of the system towards MOORA method and prioritizing the causes of delay in projects.

The seventh step: Using the MOORA reference point attitude and prioritizing the causes of delay in projects.

The eighth step: Using normal multiply method prioritizing the causes of delay in projects.

The ninth step: Comparing the results of the three prioritizing attitudes mentioned in the sixth and seventh steps to determine the effect of each project agent on the delay.

The steps of the system attitude towards the Gray MOORA method

The first step: Normalizing the decision-making matrix using gray vector normalizing equation.

Equation (21):

$$\otimes x^{*}_{ij} = \frac{\otimes xij}{\sqrt{\frac{1}{2}\sum_{j=1}^{m}(\underline{xij}^2 + \overline{xij}^2)}}$$

The second step: Forming a normalized weight matrix using the weights calculated through gray entropy method.

The third step: Determining the indices of profit and cost

The fourth step: Calculating the value of r (the reference point) for each index (each level of decision-making matrix) using the following equations:

Equation (22) for profit indices (more-better):

$$\overline{ri} = \max_j \overline{x^{*}ij}$$

$$\underline{ri} = \max_j \underline{x^{*}ij}$$

Equation (23) for cost indexes (less- better):

$$\overline{ri} = \min_j \overline{x^{*}ij}$$

$$\underline{ri} = \min_j \underline{x^{*}ij}$$

When forming the D matrix, the absolute value of the gray difference for each weighed normal gray matrix entry is from its corresponding reference point. After forming this matrix for agents of the project (the employer, contractor and the consultant) who are going to be prioritized, the gray number is made. The lower limit of this number is the maximum of the lower limit of gray entry related to this factor in D matrix and its higher limit is the maximum of the higher limit of gray entry related to this alternative in D matrix.

This gray number which is calculated for each alternative turns to its corresponding certain number and the minimum calculated certain number which is related to any of the alternatives will have the first priority. In this research, the first priority has the most effect in creating the delay in the local electricity power company of Fars province.

Equation (24):

$$A^{*}_{RP} = \{aj \mid \min i \ \ \max j \ \ dij\}$$

The general steps of complete multiply method using gray data

The first step: Normalizing the decision-making matrix using gray vector normalizing equation
The second step: Forming weighed normalized matrix using the calculated weights through Shannon's entropy method

The third step: Determining the profit and cost indices

The fourth step: Using the gray multiply equation for each alternative, the gray numbers related to the profit indices of that alternative are multiplied by each other and the gray numbers related to the cost indices of that alternative are also multiplied by each other and using the following equations, the values of A and B are calculated for each alternative:

Equation (25):

$$A_i = \prod_1^g xij^{*}$$

$$B_i = \prod_{i=g+1}^{n} xij^{*}$$

The fifth step: Calculating the basic degree of each alternative

Through dividing the multiplication sum of the profit indices by the multiplication sum of the cost indices of the alternative, the basic degree of each alternative is calculated through equation (26):

$$U_i = \frac{Ai}{Bi}$$

If the numerator or the denominator of the fraction is zero, a process of filtering or eliminating the index from the decision-making matrix is conducted.

The sixth step: Using the mentioned equations, the basic degree of each alternative which is a gray number turns to a certain number. Each alternative that has the higher basic degree is the first priority and in this research, it shows the maximum contribution to the project delay.

Research attitude

In this research, the agents cause the delay in executing the projects are the employee, consultant, contractor No. 1, contractor No. 2 and contractor No. 3. To assess the requirements, evaluating each of 10 identified causes of delay related to these agents should be critically analyzed. Furthermore, considering the importance of the consequences of the delay in projects and inappropriate decision making, to reduce the losses, the prioritizing should be conducted more precisely. In this study, the prioritizing is conducted using the three f attitudes of the reference point, system ratio, and complete multiplication. Then the responses are compared with each other. Finally, the priority which is close to the calculated priority of the three attitudes is selected.

Findings

Through interviews and library resources, 10 causes of delay which were common among the agents of the project were identified. Table 2 shows a conceptual model of this finding. The 10 identified causes are indicated with circles and the agents which cause a delay in the project are shown by squares.

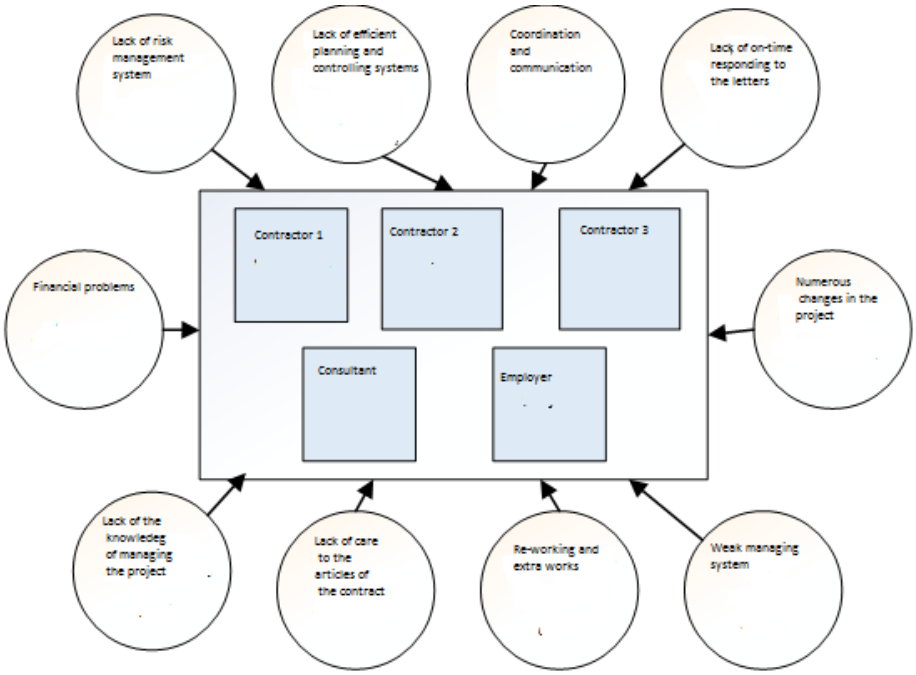

Figure 1 The conceptual model of identified causes of delay which are common among the agents of the project

The questionnaire was distributed among 26 experts. The results of decision-making matrix of the average responses are indicated in table 2.

Table 2 Decision-making matrix of the experts' average responses

Agents / Causes	Contractor 1		Contractor 2		Contractor 3		Employer		Consultant	
	L	U	L	U	L	U	L	U	L	U
Coordination and communication	4.4	8.5	8.3	2.5	6.1	3	2.2	6.3	2.2	4.3
Lack of efficient planning and controlling system	7	8.8	8.2	4	4.5	2.7	6.3	6.4	4	5

Lack of risk management system	4.4	4.5	2.3	4.4	4	5	8.3	8.4	4	5
Finantial problems	2.5	4.7	6.3	6.4	8.1	4.3	8.2	4	4.2	8.3
Lack of managing knowledge	2.5	7	8.6	2.8	3	4	6.5	8.7	7	8.8
Lack of care to the articles of the contract	4.6	6.8	8.4	2.6	2.7	4.9	8.3	8.4	4	5
Re-working and extra works	2.7	4.6	8.7	6.9	4.5	2.7	8.7	6.9	8.7	6.9
Weak management system	4.8	8.9	2.7	4.9	2.7	4.9	7	8.8	2.7	4.9
Numerous changes to the project	8.7	6.9	8.7	6.9	4.5	2.7	8.7	6.9	8.7	6.9
Lack of on-time response to the letters	6.3	6.4	2.2	2.3	8.5	4.8	8.3	8.4	8.3	8.4

To weigh the causes of the delay, Shannon's weighing method was used. To do it, using normalization method, first, the making decision matrix for gray data is normalized and then, according to table 3, the indices are calculated.

Table 3 Calculating the weight of indices

	The weight of indices X=X*LN X															
Agents / reasons	Contractor 1		Contractor 2		Contractor 3		Employer		Consultant		E		D		W	
	L	U	L	U	L	U	L	U	L	U						
R_1	-0/36	-0/36	-0/35	-0/35	-0/25	-0/28	-0/29	-0/30	-0/29	-0/29	0/9566	0/9792	0/0434	0/0208	0/2169	0/1327
R_2	-0/36	-0/36	-0/28	-0/278	-0/34	-0/34	-0/29	-0/29	-0/31	-0/30	0/9680	0/9721	0/0320	0/0279	0/1598	0/1781
R_3	-0,/34	-0,/30	-0,/31	-0,/33	-0,/33	-0,/32	-0,/32	-0,/32	-0,/33	-0,/32	-0,/32	0,/9967	0,/0033	0,/0014	0,/01649	0,/00907
R_4	-0,/37	-0,/36	-0,/34	-0,/32	-0,/25	-0,/28	-0,/31	-0,/30	-0,/28	-0,/30	0,/9588	0,/9730	0,/04412	0,/0270	0,/20601	0/17235
R_5	-0,/31	-0,/32	-0,/35	-0,/34	-0,/24	-0,/24	-0,/32	-0/33	-0/35	0/34	0/9769	0/9807	0/0231	0/093	0/11515	0/12328
R_6	-0/34	-0/35	-0/31	-0/31	-0/35	-0/36	-0/28	-0/28	-0/29	-0/28	0/9799	0/9765	0/0201	0/0235	0/10044	0/15005
R_7	-0/32	-0/32	-0/33	-0/32	-0/30	-0/32	-0/33	-0/32	-0/33	-0/33	0/9799	0/9998	0/0022	0/0002	0/01054	0/00127
R_8	-0/34	-0/33	-0/32	-0/32	-0/32	-0/32	-0/32	-0/31	-0/32	-0/32	0/9985	0/9996	0/0015	0/0004	0/00732	0/00270
R_9	-0/33	-0/33	-0/33	-0/33	-0/28	-0/29	-0/33	-0/33	-0/33	-0/33	0/9942	0/9963	0/0058	0/0037	0/02901	0/02368
R_{10}	-0/31	-0/31	-0/25	-0/26	-0/36	-0/37	-0/32	-0/31	-0/32	-0/31	0/9823	0/9679	0/0227	0/0324	0/13840	0/20694

Using vector normalization method, the average matrix of the 26 experts' responses was normalized. Then, each cause is multiplied by the weights calculated through gray entropy method and the weighed normalized matrix is calculated according to table 4.

Table 4 The weighted normalized matrix

Agents / reasons	Contractor 1		Contractor 2		Contractor 3		Employer		Consultant	
	L	U	L	U	L	U	L	U	L	U
R_1	0/0698	0/1502	0/0602	0/1347	0/0254	0/0777	0/0349	0/0933	0/0349	0/0881
R_2	0/0904	0/1267	0/0362	0/0576	0/0697	0/1036	0/0465	0/0662	0/0517	0/0720
R_3	0/0040	0/0090	0/0029	0/0073	0/0037	0/0083	0/0035	0/0080	0/0037	0/0083
R_4	0/0959	0/1631	0/0664	0/1014	0/0332	0/0749	0/0516	0/0882	0/0443	0/0837
R_5	0/0407	0/0586	0/0532	0/0687	0/0235	0/0335	0/0438	0/0653	0/0548	0/0737
R_6	0/0457	0/0919	0/343	0/0662	0/0515	0/1004	0/0272	0/0512	0/0286	0/0534
R_7	0/0005	0/0051	0/0005	0/0053	0/0004	0/0050	0/0005	0/0053	0/0006	0/0054
R_8	0/0012	0/0038	0/0010	0/0036	0/0010	0/0036	0/0010	0/0034	0/0010	0/0036
R_9	0/009	0/0150	0/009	0/0150	0/0069	0/0112	0/0099	0/0150	0/009	0/0150
R_{10}	0/0466	0/0891	0/0285	0/0620	0/0751	0/1627	0/0492	0/0930	0/0492	0/0930

Prioritizing with 'ratio system" approach of Gray MOORA method

After calculating the gray difference between the reduced profit and the increased cost of the project which are due to the agents and causes of delay, according to table 5, the gray numbers turn to certain numbers.

Table 5 The matrix of ratio system approach

Agents / reasons	Contractor 1		Contractor 2		Contractor 3		Employer		Consultant	
	L	U	L	U	L	U	L	U	L	U
R_1	0/0698	0/1502	0/0602	0/1347	0/0254	0/0777	0/0349	0/0933	0/0349	0/0881
R_2	0/0904	0/1267	0/0362	0/0576	0/0697	0/1036	0/0465	0/0662	0/0517	0/0720
R_3	0/0040	0/0090	0/0029	0/0073	0/0037	0/0083	0/0035	0/0080	0/0037	0/0083
R_4	0/0959	0/1631	0/0664	0/1014	0/0332	0/0749	0/0516	0/0882	0/0443	0/0837
R_5	0/0407	0/0586	0/0532	0/0687	0/0235	0/0335	0/0438	0/0653	0/0548	0/0737
R_6	0/0457	0/0919	0/343	0/0662	0/0515	0/1004	0/0272	0/0512	0/0286	0/0534
R_7	0/0005	0/0051	0/0005	0/0053	0/0004	0/0050	0/0005	0/0053	0/0006	0/0054
R_8	0/0012	0/0038	0/0010	0/0036	0/0010	0/0036	0/0010	0/0034	0/0010	0/0036

R_9	0/009	0/0150	0/009	0/0150	0/0069	0/0112	0/0099	0/0150	0/009	0/0150
R_{10}	0/0466	0/0891	0/0285	0/0620	0/0751	0/1627	0/0492	0/0930	0/0492	0/0930
The difference between profit and cost indices	0/2119	0/3326	0/1617	0/2507	0/0298	0/0383	0/1081	0/1844	0/1156	0/1868
The certain number of causes of delay	0/2723		0/2062		0/0341		0/1464		0/15122	

In "ratio system" approach of Gray MOORA method, based on the row of the difference between the profit and cost indices, as the highest number belongs to contractor 1, he has the most contribution to delay of the Fars province local electricity power company. Furthermore, he is the first priority of determined causes of delay. So, in order to reduce the delay, he should first be assessed. Contractor 2, the consultant, the employer and contractor 3 are the second to the fifth priorities.

Prioritizing with reference point attitude

In this method, first, the reference point o all identified causes of delay is determined and then the absolute value of each entry from the related reference point is calculated and the results will be shown as table 6.

Table 6 The matrix of the absolute value of each entry deviation from the reference point

Agents / reasons	Contractor 1		Contractor 2		Contractor 3		Employer		Consultant		Reference point	
	L	U	L	U	L	U	L	U	L	U	L	U
R_1	0/000	0/000	0/010	0/016	0/044	0/073	0/035	0/057	0/035	0/062	0/070	0/0150
R_2	0/000	0/000	0/054	0/069	0/021	0/023	0/044	0/060	0/039	0/055	0/090	0/127
R_3	0/001	0/002	0/000	0/000	0/001	0/001	0/001	0/001	0/001	0/001	0/029	0/007
R_4	0/000	0/000	0/030	0/062	0/063	0/088	0/044	0/057	0/052	0/079	0/096	0/163
R_5	0/014	0/015	0/002	0/005	0/031	0/040	0/011	0/008	0/000	0/000	0/055	0/074
R_6	0/019	0/015	0/007	0/015	0/024	0/049	0/001	0/000	0/001	0/002	0/027	0/051
R_7	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/001	0/005
R_8	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/000	0/001	0/004
R_9	0/000	0/000	0/000	0/000	0/003	0/004	0/000	0/000	0/000	0/000	0/010	0/015
R_{10}	0/018	0/027	0/000	0/000	0/047	0/0101	0/021	0/031	0/021	0/031	0/029	0/062

In prioritizing through reference point method, contractor 1 is in the first priority as he has the least value. Then, contractor 2, the employer, consultant and contractor 3 are in the second to fifth priority.

Prioritizing the agents who cause the delay through the complete multiplication attitude

In this approach, first, for each agent that causes the delay (the employer, consultants, and contractors) the profit indices are multiplied by

each other and cost indices are multiplied by each other. Finally, the sum of dividing the profit indices by cost indices is calculated which is shown in table 7.

Table 7 Dividing profit indices (causes of delay) by cost indices for each agent

Contractor 1		Contractor 2		Contractor 3		Employer		Consultant	
L	U	L	U	L	U	L	U	L	U
$1/90*10^{-9}$	$6/21*10^{-6}$	$1/35*10^{-9}$	$5.62*10^{-6}$	$3.13*10^{-11}$	$2.95*10^{-7}$	$4.94*10^{-10}$	$2/05*10^{-6}$	$6/01*10^{-10}$	$2/22*10^{-6}$

For easier comparing the agents of the delay, using the gray number to the certain number converting equations, the numbers in table 7 are converted to certain numbers or table 8.

Table 8 The certain values of gray numbers

Contractor 1	Contractor 2	Contractor 3	Employer	Consultant
$3/10*\ 10^{-6}$	$2/11*10^{-6}$	$0/147*10^{-6}$	$1/029*10^{-6}$	$1/114*10^{-6}$

According to table 8, the maximum number belongs to contractor 1. So, according to MULTIMOORA complete multiplication approach, he has the first priority of delay causes in the projects of Fars regional electricity power company and contractor 2, the consultant, employer and contractor 3 are the second to fifth priorities, in respect.

Summarizing the prioritization based on three ratio system, reference point, and complete multiplication approaches

Table 9 shows the general result of prioritizing the agents causing delay based on the three approaches.

Table 9 The simultaneous prioritizing based on the results of the three approaches

The first priority	The second priority	The third priority	The fourth priority	The fifth priority
Contractor 1	Contractor 2	The consultant	The employer	Contractor 3

The certain weight of the identified causes of delay

In this research, using the gray entropy weighing method, the weight of causes (indices) was calculated. According to table 9, the reasons that cause a delay in which all 5 agents (the employer, consultant and the three contractors) had close priories (based on the decision makers' opinion), had less weight than the other indices.

Table 10 The certain weight of the causes of delay (indices)

Reasons for delay	Coordination and communication	Lack of efficient planning and controlling	Lack of risk management system	Financial problems	Lack of managing knowledge	Weak management system	Re-working and extra works	Lack of care to the articles of the contract	Numerous changes in the project	Lack of on-time response to the letters
Code of reasons	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
The certain weight	0/174	0/169	0/012	0/0189	0/119	0/125	0/005	0/005	0/026	0/172

The calculated certain weight shows that the most effective causes of delay in projects which are due to the agents are lack of on-time response to the letter, weak coordination and communication and weak management in planning and controlling system.

Discussion

In this research, through interviews with 26 experts of the regional electricity power company of Fars province and distributing questionnaires among them, 10 main causes of delay in projects which were common among the agents (the employer, contractor and consultant) were identified and using gray entropy, they were weighed. This research includes in the following innovations:

1. Finding the most important causes of delay which are common in the agents of the project.
2. Using gray numbers in decision making matrix and gray weighing using gray entropy method.
3. Prioritizing the agents of the delay (the employer, consultant and contractor) using three different approaches of MOORA method.
4. Final prioritizing the agents of delay the simultaneous use of the results of the three MOORA approaches.

Figure 1 (above mentioned) shows the suggested conceptual model of the reasons and the agents of the delay in the projects of electricity power-company in Fars province. Figure 3 shows the calculated weights of the 10 identified reasons of the delay.

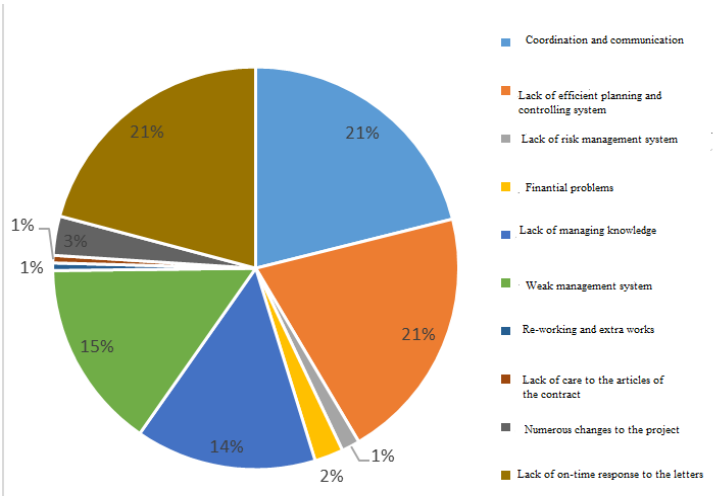

Figure 3 The certain weight of delay causes

Comparing the results of this study with the other researches on the weight of indices shows that management and system weaknesses such as lack of coordination and lack of on-time

responses are more important than non-management causes of delays such as numerous changes to the project and financial problems. So, it can be concluded that the responses of the experts and the results of other researches on the non-management causes of delay are almost close to each other and the diversity of responses are mostly seen in some managing and specialized indices. The employer, consultant and contractor 3 are agents of delay who were prioritized through three approaches of Gray MULTIMOORA i.e. "ratio system", "reference point" and "complete multiplication". The results are shown in table 11.

Table 11 A summary of the prioritization of agents based on three approaches of Gray MULTIMOORA method

Approach / Priority	Gray MOORA ratio system approach	Gray MOORA reference point approach	Gray MOORA complete multiplication approach	The simultaneous combination of the three Gray MOORA approaches
The first priority	Contractor 1	Contractor 1	Contractor 1	Contractor 1
The second priority	Contractor 2	Contractor 2	Contractor 2	Contractor 2
The third priority	The consultant	The employer	The consultant	The consultant
The fourth priority	The employer	The consultant	The employer	The employer
The fifth priority	Contractor 3	Contractor 3	Contractor 3	Contractor 3

The results of prioritizing the Gray MOORA "ratio system", "reference point" and complete multiplication approaches are the same except the third and fourth priorities which are quite different.

When due to the sensibility of the issue and the necessity of evaluating all indices (cause of the delay), the experts believe that the agents (the employer, consultant, and contractor) are not acceptable even due to a very insignificant reason, the Gray MULTIMOORA 'ratio point" approach is used to eliminate the undesirable alternatives and reduce the sample space. Hence, if the decision makers accept the weakness of an index while other indices are strong, 'ratio point" approach is not an appropriate tool for prioritizing the agents of delay.

In "reference point" approach, if the experts change their attitudes towards one cause of delay (the weak index of delay agents), the prioritization will be affected while in "complete multiplying" and "ratio system" approach, if the experts change their attitudes towards one cause of delay, it is nearly impossible to displace the priorities as there are many identified causes (10 causes) that are common in the agents of the delay.

One of the goals of this research is to evaluate the previous performance of the regional electricity power company in Fars province based on the results of this study. In this regard, it can be said that the previous performance of the company shows that it did not pay enough attention to the delays in the project and it believed that just technical reasons were the causes of delays.

Suggestions

1. In this research, the gray entropy weighing method was used to weigh the reasons of delay in projects. It is suggested that using another questionnaire, a survey on the degree of importance of delay causes be conducted. Then the results of this weighing are compared with the results of the weights which were calculated

using the gray entropy weighing method to prioritize the delay agents.

2. It is suggested that in order to reach more comprehensive results, more delay causes be evaluated when prioritizing the causes of delay.
3. The group of experts contained 26 managers related to the project who were in access. It is suggested that if it is possible, more experts be used in a similar study. This way, the prioritizing the delay causes will be conducted faster and the results will be more precise. So, the causes of the delay will be better managed and the delay will be reduced.
4. It is suggested that to make decisions on other issues such choosing the contractors who take part in the bids, the regional electricity power company of Fars province uses MULTIMOORA method and considers appropriate indices.
5. In all the three MULTIMOORA approaches, contractor 3 has been determined as the last cause of delay in projects. It means that his performance was better than the other agents of the project. So, it is suggested that in executing other projects, take more advantage of the presence of contractor 3 and in the future projects, be more careful about choosing contractors 1 and 2.
6. Considering that the main common causes of delay are lack of coordination and communication and weak managing the planning and controlling the project which are due to the weakness of the project agents' teamwork, it is suggested that in order to determine the way of communication, coordination and reporting to the planning and controlling managers, an execution method and its regulations (instruction) be prepared.
7. Considering that according to MULTIMOORA method, the employer and the consultant are the third and fourth causes of delays, it is suggested that through holding managing delay and project knowledge courses, improve the qualifications of the managers and reduce the delays.

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