Assessing the causes of construction projects delays in the developing countries: Case of Iraq

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ABSTRACT

The research proposes a modified Fuzzy- Failure Model and Effects Analysis model to assess the level of significance of the root causes of construction projects delays. The proposed model considers the Expected Cost Level (E.C.L) which measures the expected level of the financial cost needed to overcome the risky event. The assessment was performed under a fuzzy environment to resolve the ambiguity that comes with human knowledge and decision-making process. When compared to the conventional Fuzzy-FMEA model, results indicated high accuracy in the assessment for the Root Causes of Construction Projects Delays (RCCPD). It was found that the top five RCCPD based Fuzzy-FMEA model are lack of testing facilities (F-RPN=0.80), followed by site accidents (F-RPN=0.79), environmental factors (F-RPN=0.69), poor communication and site coordination (F-RPN=0.67), and lack of skilled and unskilled workers (F-RPN=0.65). On the other hand, it was found that the top five RCCPD based on the Modified Fuzzy-FMEA model are site accidents (MF-RPN=0.98) followed by lack of skilled and unskilled workers (MF-RPN=0.91), lack of testing facilities (MF-RPN=0.90), escalation in materials prices (MF-RPN=0.87), and material shortage (MF-RPN=0.86). Furthermore, the proposed model should encourage construction professionals and researchers to adopt it when assessing the causes of delays and other causes of system failures in different engineering contexts.

Introduction

Completion of a project within the specified period of time is one of the vital factors for the project's success (Zemra et al., 2009). Nevertheless, the majority of construction projects encounter schedule delays. Generally, project delay is defined as an overrun of time beyond the agreed completion date, and this issue had actually come to be a persistent issue, particularly in the developed countries **(**Durdyev and Hosseini, 2020). Assessing the Root Causes of Construction Projects Delays (RCCPD) have been carried out extensively. However, the vast majority of these studies depend on conventional decision-making acts that are based on personal experience and intuition, such as Failure Mode & Effects **(**Lee et al., 2019), which depends on three assessment dimensions, namely likelihood Level (L.L), Impact Level (I.L), and Detection Level (D.L).. these subjective judgments when performing the assessment is subjected to epistemic uncertainties (Dıaz-Curbelo and Andrade, 2020), resulting from lack of information. The assessment in this research is performed under the fuzzy environment to capture the uncertainties caused by ambiguity or lack of knowledge.

Methodology

A mixed method of qualitative and qualitative approaches was adopted in this research to identify and assess the RCCPD. The decision of the selected research methods depends on the study nature, the purpose of the research, research objectives, the availability of the resources and previous literature (Al-Mhdawi., 2020; Al-Mhdawi et al., 2020). In this research, we targeted key construction stakeholders (architects, general contractors and project managers) for the qualitative and quantitative data collection stages. We excluded clients/owners as the focus was on the perceived RCCPD by the day-to-day involved key stakeholders during the project lifecycle. Our exclusion for clients is because their involvement during the project Lifecycle is minimal (this is the case in the majority of developing counties like Iraq) regardless of the contract type; this is because project managers act on behalf of them during the project lifecycle.

First, we identified the RCCPD through semi-structured interviews with 9 Iraqi key construction stakeholders, and then we administrated 119 questionnaire survey to assess the RCCPD levels of significance based on the key experts' opinions. Finally, we developed a modified Fuzzy-FMEA assessment model (MF-FAM) to analyze and prioritize the identified RCCPD.

The development of RCCPD using modified FMEA based on FST

Failure mode and effects analysis is used to assess and prioritize potential failures within a system (Sultan and Haq, 2011). This approach is widely used by scholars construction industry to assess and prioritize potential failures within a system (Sultan and Haq, 2011). In the construction industry, this technique analyses the root causes of failures and defines the total impact on the project set objectives (see e.g. Oliveros and Fayek, 2005; Abdelgawad and Fayek, 2010; Abdelgawad and Fayek, 2012; Mohammadi and Tavakolan, 2013; Ahmadi et al., 2016; Mete, 2019; Khalilzadeh et al., 2020; Alvand et al., 2021 and others). The FMEA model consists of the following parameters (Prakash et al., 2015): Likelihood Level (estimates the probability of failure occurrence); Impact Level: (estimates the impact of failures on project objectives); Detection level (measures the ability to identify a potential failure before its occurrence which means how detectable is the failure while something is still could be done, also called detectability); and Risk Priority Number (RPN) (which is a number used to express the priority of the failure where"

RPN = L.L * I.L * D.L……….(eq.1)

It is an appropriate assessment tool that helps decision-makers to identify potential failure modes and rank them in order of importance so that measures are taken to reduce the level of likelihood of failure modes (Wang et al., 2009). However, several limitations are linked with its sensible application in actual work implementation in different industries. The main Drawbacks of traditional FMEA
are (Khasha et al., 2013):

1) Different combinations of (L.L), (I.L) and (D.L) may lead to an identical RPN value; however, failure modes with an identical RPN may correspond to different failure modes

2) In conventional FMEA, (L.L), (I.L) and (D.L) are assumed to be of the same significance. However, in reality, the degree of their importance may vary.

We used Fuzzy Set Theory (FST) in this study to reconcile ambiguity associated with human knowledge and decision making, in order to overcome the limitations of conventional FMEA (Al-Mhdawi, 2020). The novelty of this model includes considering other criteria besides the (L.L), (I.L) and (D.L). The new criteria is the Expected Cost Level, which measures the expected level of the financial cost needed to overcome the risky event

Thus, the modified RPN = L.L * I.L * D.L* E.C.L ………………. (2)

The RCCPD assessment model based on a modified Fuzzy-FMEA is presented in Fig. 1. First, we ranked the (L.L), (I.L), (D.L) and (E.C.L) for each RCCPD based on the criteria presented in Table 1. Second, we calculated the RPN for each RCCPD using equation (2). Last, we used MATLAB to fuzzify the (L.L), (I.L), (D.L) and (**E.C.L**) using a triangular-shaped membership function. We used the Mamdani-type inference controllers to define the system's behavior through the establishment of IF-THEN rules. Finally, the outputs from the fuzzy interference system were defuzzied using the centroid method to obtain the Modified Fuzzy- Risk Priority Numbers (MF-RPNs).

Table 1. The Modified FMEA likelihood, impact, detection, AND Expected Cost Level level scale

Score	Likelihood/Impact	Detection/Expected Cost Level
1	Very low	Very high
2	Low	High
3	Moderate	Moderate
4	High	Low
5	Very high	Very low

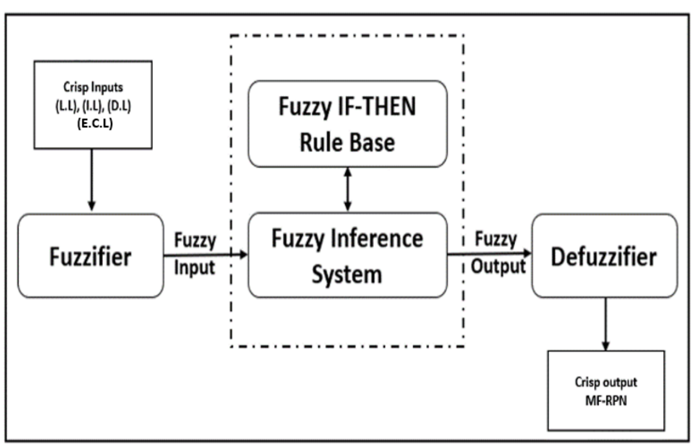

Fig. 1. The modified FMEA-fuzzy assessment model for RCCPD

Results and conclusion

The experts' interviews yielded 15 key RCCPD, namely: delay in site mobilization (D1); late approval/evaluation of the accomplished work (D2); engineering drawings problems (delay& mistake) (D3); poor communication and site coordination (D4); lack of managerial and supervisory skills (D5); lack of skilled and unskilled workers (D6); delay in contractor's payments (D7); an escalation in materials prices (D8); equipment shortage (D9); material shortage (D10); lack of testing facilities (D11); ill security (D12); environmental factors (D13); conflict among stakeholders (D14); and site accidents (D15). The input variables to the MF-FAM are (L.L), (I.L), (D.L), and (E.C.L). We used 625 IF-THEN rules. Each variable (cases of delays) has five attributes: very low, low, moderate, high, and very high. On the other hand, the proposed model's output variable is Modified Fuzzy-Risk Priority Number (MF-RPN) (See Fig. 2).

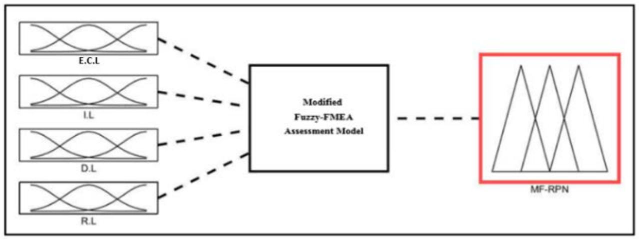

Fig.2. Fuzzy inputs and outputs variables

We have also performed Fuzzy-FMEA and calculated Fuzzy Risk Priority Number (F-RPN) for comparison. The Fuzzy-FMEA model has three input variables, namely (L.L), (I.L), (D.L); 125 IF-THEN rules; and one output variable (F-RPN). It can be indicated from Table (2) that the order of the top five RCCPD based on the Fuzzy-FMEA model are D11 (F-RPN=0.80), D15 (F-RPN=0.79), D13 (F-RPN=0.69), D3 (F-RPN=0.67), and D6 (F-RPN=0.65). On the other hand, it was found that the top five RCCPD based on the Modified Fuzzy-FMEA model is D15F (MF-RPN=0.98) followed by D6 (MF-RPN=0.91), D11 (MF-RPN=0.90), D8 (MF-RPN=0.87), and D10 (MF-RPN=0.86). We can observe from the results that the Fuzzy-FMEA model compares the Modified Fuzzy-FMEA model, provides a more representative assessment of RCCPD. It is concluded from this investigation that adding the Expected Cost Level as an additional assessment dimension/scale to the Fuzzy-FMEA model had provided a more accurate assessment for the RCCPD by addressing the blind spot of the three-dimensional assessment criteria in which it permits the experts to use their experience, expertise and knowledge when performing RCCPD assessment. Also, the use of the Modified model can improve and enhance the understanding of the complex problems' dynamics in which decisions are to be made from vague information; and can enhance the degree of accuracy level of RCCPD assessment and prioritization.

Table.2 Fuzzy-FMEA and Modified Fuzzy-FMEA assessment outputs

RCCPD	Likelihood level	Impact level	Detection level	Fuzzy-FMEA		Expected Cost Level	Modified F-FMEA	
	Triangular Number	Triangular Number	Triangular Number	F-RPN	Rank	Triangular Number	MF-RPN	Rank
D1	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.59	8	(0.25, 0.5, 0.75)	0.81	8
D2	(0.25, 0.5, 0.75)	(0.75, 1, 1.25)	(- 0.25, 0, 0.25)	0.51	13	(0, 0.25, 0.5)	0.62	15
D3	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.67	4	(0, 0.25, 0.5)	0.83	7
D4	(0.5, 0.75, 1)	(0.75, 1, 1.25)	(- 0.25, 0, 0.25)	0.58	9	(0, 0.25, 0.5)	0.69	14
D5	(0.25, 0.5, 0.75)	(0, 0.25, 0.5)	(0, 0.25, 0.5)	0.47	15	(0.25, 0.5, 0.75)	0.71	13
D6	(0.25, 0.5, 0.75)	(0.75, 1, 1.25)	(0, 0.25, 0.5)	0.65	5	(0.25, 0.5, 0.75)	0.91	2
D7	(0, 0.25, 0.5)	(0.75, 1, 1.25)	(0.25, 0.5, 0.75)	0.54	11	(0, 0.25, 0.5)	0.79	9
D8	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.56	10	(0.25, 0.5, 0.75)	0.87	4
D9	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.53	12	(0.25, 0.5, 0.75)	0.84	6
D10	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.61	7	(0, 0.25, 0.5)	0.86	5
D11	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	0.80	1	(0.25, 0.5, 0.75)	0.90	3
D12	(0.5, 0.75, 1)	(0.75, 1, 1.25)	(0, 0.25, 0.5)	0.62	6	(0, 0.25, 0.5)	0.77	10
D13	(0.25, 0.5, 0.75)	(0.75, 1, 1.25)	(0, 0.25, 0.5)	0.69	3	(0.25, 0.5, 0.75)	0.75	11
D14	(0, 0.25, 0.5)	(0.5, 0.75, 1)	(0, 0.25, 0.5)	0.49	14	(0.25, 0.5, 0.75)	0.73	12
D15	(0.5, 0.75, 1)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	0.79	2	(0.25, 0.5, 0.75)	0.98	1

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.

References

1) Abdelgawad, M. and Fayek, A. R. (2010) "Risk management in the construction industry using combined fuzzy FMEA and fuzzy AHP," Journal of construction engineering and management, 136(9), pp. 1028–1036.
2) Abdelgawad, M. and Fayek, A. R. (2012) "Comprehensive hybrid framework for risk analysis in the construction industry using combined failure mode and effect analysis, fault trees, event trees, and fuzzy logic," Journal of construction engineering and management, 138(5), pp. 642–651.
3) Ahmadi, M. et al. (2016) "Comprehensive risk management using fuzzy fmea and mcda techniques in highway construction projects," Journal of civil engineering and management, 23(2), pp. 300–310.
4) Al Mhdawi, M. K. (2020) "Proposed risk management decision support methodology for oil and gas construction projects," in Lecture Notes in Mechanical Engineering. Singapore: Springer Singapore, pp. 407–420.
5) Al Mhdawi, M. K. (2020) "Proposed risk management decision support methodology for oil and gas construction projects," in Lecture Notes in Mechanical Engineering. Singapore: Springer Singapore, pp. 407–420.
6) Alvand, A. et al. (2021) "Identification and assessment of risk in construction projects using the integrated FMEA-SWARA-WASPAS model under fuzzy environment: a case study of a construction project in Iran," International journal of construction management, pp. 1–23.
7) Durdyev, S. and Hosseini, M. R. (2019) "Causes of delays on construction projects: a comprehensive list," International journal of managing projects in business, 13(1), pp. 20–46.

8) Khalilzadeh, M., Balafshan, R. and Hafezalkotob, A. (2020) “Multi-objective mathematical model based on fuzzy hybrid multi-criteria decision-making and FMEA approach for the risks of oil and gas projects,” Journal of Engineering Design and Technology, 18(6), pp. 1997–2016.
9) Khasha, M. S. and Khatibi, T. (2013) “A fuzzy FMEA approach to prioritizing surgical cancellation factors,” International Journal of Hospital Research, 2(1), pp. 17–24.
10) Lee, Dongyoun et al. (2019) “Assessment of delay factors for structural frameworks in free-form tall buildings using the FMEA,” International journal of concrete structures and materials, 13(1). doi: 10.1186/s40069-018-0309-9.
11) M Kavitha, Zaid Hamid Mahmoud, Kakarla Hari Kishore, AM Petrov, Aleksandr Lekomtsev, Pavel Iliushin, Angelina Olegovna Zekiy, Mohammad Salmani. application of Steinberg Model for Vibration Lifetime Evaluation of Sn-Ag-Cu-Based Solder Joints in Power Semiconductors. IEEE Transactions on Components, Packaging and Manufacturing Technology. 2021; 11(3) 444-450.
12) Mohammadi, A. and Tavakolan, M. (2013) “Construction project risk assessment using combined fuzzy and FMEA,” in 2013 Joint IFSA World Congress and NAFIPS Annual Meeting (IFSA/NAFIPS). IEEE.
13) Oliveros, A. V. O. and Fayek, A. R. (2005) “Fuzzy logic approach for activity delay analysis and schedule updating,” Journal of construction engineering and management, 131(1), pp. 42–51.
14) Prakash, A. M. J., Senthilvelan, T. and Gnanadass, R. (2015) “Optimization of process parameters through fuzzy logic and genetic algorithm—A case study in a process industry, Appl,” Soft Comput, 30.
15) Rachid, Z., Toufik, B. and Mohammed, B. (2019) “Causes of schedule delays in construction projects in Algeria,” International journal of construction management, 19(5), pp. 371–381.
16) Sultan, J. H. (2011) “Risk Analysis Method: FMEA/FMECA in the Organizations,” International Journal of Basic & Applied Sciences, 11(05), pp. 74–82.“The role of fuzzy logic to dealing with epistemic unvertanity in supply chain risk assessment: review standpoints,Int” (no date) J. Fuzzy Syst.
17) Wang, Y.-M. et al. (2009) “Risk evaluation in failure mode and effects analysis using fuzzy weighted geometric mean,” Expert systems with applications, 36(2), pp. 1195–1207.
18) Zaid Hamid Mahmoud, Hanif Barazandeh, Seyed Mojtaba Mostafavi, Kirill Ershov, Andrey Goncharov, Alexey S Kuznetsov, Olga D Kravchenko, Yu Zhu. identification of rejuvenation and relaxation regions in a Zr-based metallic glass induced by laser shock peening. Journal of Materials Research and Technology. 2021, 11; 2015-2020.