Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 1, 2020

Original Article

IMPROVING OF THE CONSTRUCTION PROJECT RISK EVALUATION BASED FMEA MODEL USING HYBRID APPROACH UNDER FUZZY ENVIRONMENT

ABOLFAZL ALVAND[1], S. MOHAMMAD MIRHOSSEINI[1]*, MOHAMMAD EHSANIFAR[2], EHSANOLLAH ZEIGHAMI[1], AMIR MOHAMMADI[1]

[1]Department of Civil Engineering, Arak Branch, Islamic Azad University, Arak, Iran.
[2] Department of Industrial Engineering, Arak Branch, Islamic Azad University, Arak, Iran.
***Email: m-mirhoseini@iau-arak.ac.ir**

Received: 10 Oct 2020 Revised and Accepted: 14 Dec 2020

ABSTRACT

This article aimed to develop a novel failure mode and effect analysis (FMEA) framework for evaluating, ranking, and improving risk modes. A hybrid approach combining fuzzy stepwise weight assessment ratio analysis (F-SWARA) and fuzzy weighted aggregated sum product assessment (F-WASPAS) is used to rank the risk of the failure modes identified in FMEA. The F-SWARA method is employed to determine the influential weights and finally, the F-WASPAS technique is used to the ranking levels for the failure modes. A case study of Iran's Road and Urban Organization is provided to illustrate the potential application and benefits of the proposed FMEA approach. Results indicated that the new risk priority model can be effective in helping analysts find the high risky failure modes and create a suitable assessment. The proposed FMEA can overcome the shortcomings and improve the effectiveness of the traditional FMEA. Also, this article presents a novel hybrid approach for improving traditional FMEA in the fuzzy environment. The results of comparative analyses indicated that the proposed approach is valid and can provide useful information in assisting risk management of construction projects.

Keywords: Construction project, Risk evaluation, FMEA, F-SWARA, F-WASPAS

DOI: http://dx.doi.org/10.22159/jcr.07.01.01

INTRODUCTION

Most projects are implemented in such a complex and dynamic environment that risk and uncertainty are their intrinsic features. This uncertainty and risk caused that most construction projects do not remarkably successful in reaching predetermined goals (Zegordi et al. 2014). Therefore, risk management and detection are an important issue for surviving and succeeding construction projects (Wideman 1992; Rahimi et al. 2018), which should be employed as an effective tool for monitoring different risks in construction projects (Wehbe and Hamzeh 2013).

Risk management mainly aims to increase the probability of project success, which is achieved through systematic risk identification and evaluation, providing methods to reduce or avoid them, and maximize opportunities (Chapman and Ward 1996). The risk management process is divided into risk evaluation (risk analysis and detection) and risk treatment (Rahimi et al. 2018). Therefore, an effective risk management process, which starts with risk evaluation and risk management, is impossible without completing the first step (Miler 2005), because performing this step properly leads to preventive and corrective actions in the subsequent risk management step (Hosseinzadeh and Gheidar Khaljani 2013).

During the recent years, various methods have been developed for evaluating risk, among which we can refer to failure mode and effect analysis (FMEA) and its effects. This method was initially used in military applications, especially in the aviation industry (Fattahi and Khalilzadeh 2018). The most important goal of applying the FMEA method is to assess potential risks, determine their causes, evaluate their effects on system performance, and finally determine ways to decrease the chance of occurrences and outcomes and increase the capability of failure mode detection (Omidvar and Nirumand 2017). In FMEA traditional method, Risk Priority Number (RPN) is used to calculate the risk of system different failure modes which itself is RPN, multiplied by three-factor risks of occurrence (O), severity (S), and failure detection probability (D). More priority number in the risk leads to more failure mode in the risk. Prioritization is considered as an objective of calculating RPN. Despite widespread applications, the FMEA method is major drawbacks which restrict this method, especially when it is used to analyze criticality in calculating RPN. Traditional FMEA constraints can be expressed as follows (Omidvar and Nirumand 2017):

1. The relative importance of O, S, and D parameters are not considered in calculating PRN and their weights are considered the same, although this issue can make some constraints in real applications.
2. Different sets of O, S, and D may have similar PRN, but risk outcomes may be completely different, leading to the lack of risk success.
3. The RPN is not continuous. Many empty elements are available in the RPN scales because many numbers between 1 to 1000 cannot be obtained by the product of O, S, and D.
4. FMEA is a group risk assessment method that is not based solely on one's personal opinions. Therefore, it is difficult to extract the true value of each risk factor based on the group's view.
5. Accurate determination of O, S, and D parameters is often difficult. FMEA team members may have different assessments for similar risk factors, some of which may be inaccurate, uncertain, and inconsistent, which is created by time constraints, lack of experience and insufficient data.

To address the constraints of the usual RPN and improve the effectiveness of the traditional FMEA method, this issue has elicited considerable research attention and various approaches have been proposed to overcome the weaknesses of traditional FMEA. Among them, the fuzzy approach resolves some of the weaknesses of conventional RPN. Zadeh (1965) established the fuzzy set theory. The fuzzy FMEA method describes the three risk factors O, S, and D, using fuzzy linguistic terms. A majority of studies on fuzzy FMEA consider the fuzzy if-then conditional rule-based approach in which the conditional components or conclusions constitute linguistic variables (Fattahi and Khalilzadeh 2018). Ilbahar et al. (2018) presented a novel approach to risk assessment by combining a fuzzy inference system (FIS) with the fuzzy analytic hierarchy process (F-AHP) method. Bonato et al. (2018) evaluated risk using the fuzzy rule-based method. Mangeli et al. (2019) improved risk assessment in the FMEA method using the nonlinear model, a fuzzy modified technique for order performance by similarity to ideal solution (F-TOPSIS), and support vector machine. Unfortunately, the application of fuzzy rule-based methods is unclear because preparing and testing a complete set of fuzzy rules is a tedious and time-consuming activity. Therefore, some authors have proposed to combine fuzzy systems with multi-criteria decision-making (MCDM) methods. In this regard, Tian et al. (2018) used the combinational best-worst method (BWM), relative-entropy and VIKOR (VlseKriterijumska Optimizacija i KOmpromisno Resenje) to rank the failure modes. In this study, failure modes were selected as evaluating options and risk factors as criteria. They considered the relative weights of risk factors in its method for risk assessment and improved risk assessment results by considering the relative importance of O, S, and D parameters in calculating RPN. Liu et al. (2015) proposed a hybrid MCDM approach, VIKOR, AHP, and decision-making trial and evaluation laboratory (DEMATEL) techniques to improve risk evaluation. The results indicated that the proposed FMEA can overcome the shortcomings and improve the effectiveness of the traditional FMEA. Fattahi and Khalilzadeh (2018) presented a hybrid approach based on the FMEA method, extended multiple multi-objective optimization by ratio analysis (MULTIMOORA) and AHP to improve the evaluation of the FMEA method. Safari et al. (2016) analyzed construction risks using the FMEA method and the fuzzy VIKOR method. The study aimed to detect risks and obviate the drawbacks of the FMEA and VIKOR fuzzy methods to prioritize and detect risk factors. The results of current research indicated that the most critical risks in construction projects are practical work, infrastructure, lack of modeling tools, technology, market participants, organizational environment, loss of key personnel, and information. Identifying risks helps to improve and facilitate development projects.

In another study, Vahdani et al. (2015) presented a new FMEA method by integrating fuzzy logic and TOPSIS to improve the risk assessment process. A new method for risk assessment was presented so that to resolve the weaknesses of the classic method by combining FMEA with the fuzzy TOPSIS method. The results indicated that applying the proposed method assists in prioritizing the risk based on the ideal and not ideal possible mode. Ardeshir et al. (2013) evaluated safety risks in mass projects using a combination of methods fuzzy FMEA, Fuzzy Fault Tree Analysis (F-FTA), AHP, and data envelopment analysis (DEA). Knowing the importance of risk assessment in construction projects, the present study utilized the FMEA hybrid approach, F-FTA, AHP, and DEA. The results indicated that the proposed hybrid approach could help construction site safety professionals to identify risks, detect root causes, and provide accurate risk control tools. Omidvar and Niroumand (2017) evaluated risk using the FMEA method based on the MCDM principle, fuzzy logic, and gray theory. In the study, the problem of having the same weights related to risk factors, data uncertainty regarding expert opinions, and prioritizing failure modes were eliminated by relying on the fuzzy AHP and gray theory, respectively. The results indicated that the proposed method has a higher ability in prioritization than the classical method of analyzing the modes and effects of failures.

Surveying the above literature review indicates that considerable effort has been made to overcome the weaknesses of the conventional FMEA in risk evaluation. Despite many used methods and techniques in this field, risk evaluation in the FMEA technique still needs new researches, because a little bit deviation of project objectives could result in losses. Therefore, whatever the accuracy be higher, the deviations from the goals will be less. For these reasons, this paper aims to develop a new risk evaluation model for FMEA based on a hybrid approach that combines fuzzy stepwise weight assessment ratio analysis (F-SWARA) and fuzzy weighted aggregated sum product assessment (F-WASPAS). The proposed FMEA approach overcomes the limitation associated with the conventional RPN method and its various improvements and can be used to help analysts analyze in more precise computation of RPN as well as improved the effectiveness of the FMEA method and this matter has been proved by researches. Finally, a case study of the Central Library construction project is presented to illustrate the effectiveness and benefits of the proposed approach.

The rest of the article is organized as follows. An introduction of the traditional FMEA analysis method, F-SWARA, and F-WASPAS method is presented in the section 'Preliminaries'. In Section 'The proposed hybrid approach to improve risk evaluation', we present a novel hybrid approach based on FMEA model the research implementation algorithm. Section 'Case study' presents a case study and empirical results using the proposed hybrid approach to improve and evaluate the risks of construction projects. Finally, Discussion and conclusions are presented in the following sections, respectively.

PRELIMINARIES

The traditional FMEA analysis method

FMEA is a structured teamwork-based tool used to define, identify, evaluate, prevent, remove, or control the causes and effects of potential risks in a system and project process, before delivering the product or service to the customer (Liu 2016). In other words, FMEA analysis is an analytical method of risk evaluation that tries to identify the potential risks in the areas in which the risk evaluation is performed, as well as recognizing and rank its related causes and effects. FMEA method is one of the most experienced and useful methods for identifying, classifying, analyzing failures, and assessing the risks associated with them. The number of failures can be derived by this method and prevent its occurrence in the future (Liu et al. 2013). To identify potential risks and their causes and effects, the FMEA team often uses collected information about the performance of the previous generation of a project.

If such information is not available, the team's information and experiences are used. Proper implementation of failure modes analysis and its consequences can have effective results for risk detection. The next step is a critical analysis of the detected risks concerning risk occurrences (O), severity (S), and detection (D). The main purpose of FMEA is to allow analysts to prioritize the failure modes of a system, design, process, product, or service to allocate limited resources to dangerous items. Traditionally, the prioritization of failure modes in FMEA is determined through the RPN, which is identified as the multiplication of risk factors O, S, and D for each risk as follows (Liu et al. 2013):

$$RPN = O \times S \times D, \quad (1)$$

where (O) is risk occurrence, (S) is risk severity, (D) is failure detection probability, and RPN is the acronym for Risk Priority Number. Three risk factors are evaluated by experts by using a 10-point scale and the results are presented in Tables (1), (2), and (3), respectively. Failure modes can be ranked through the RPN, and then appropriate actions are arranged for the risk with a high-RPN. RPN should be recalculated after correction to see whether the risks have been reduced or not. Thus, the FMEA method is a constantly changing document that aims to provide better services (Stamatis 2003).

Table 1. Occurrence Score to Identify Risks in the FMEA (Rahimi et al. 2018; Liu 2016).

Ranking	Probability of Failure	Possible Failure Rate
10	Extremely high	≥1 in 2
9	Very high	1 in 3
8	Repeated failures	1 in 8
7	High	1 in 20
6	Moderately high	1 in 80
5	Moderate	1 in 400
4	Relatively low	1 in 2000
3	Low	1 in 15,000
2	Remote	1 in 150,000
1	Nearly impossible	≤1 in 1,500,000

Table 2. Detection Score to Identify Risks in the FMEA (Rahimi et al., 2018; Liu 2016).

Ranking	Probability of Failure
10	Absolute uncertainty
9	Very remote
8	Remote
7	Very low
6	Low
5	Moderate
4	Moderately high
3	High
2	Very high
1	Almost certain

Table 3. Severity Score to Identify Risks in the FMEA (Rahimi et al., 2018; Liu 2016).

Ranking	Effects
10	Hazardous without warning
9	Hazardous with warning
8	Very high
7	High
6	Moderate
5	Low
4	Very low
3	Minor
2	Very minor
1	None

F- SWARA method

In many Multiple Attribute Decision Making (MADM) problems, weighting the indicators is considered as one of the most critical steps in the problem. The SWARA method is, in fact, one of the newest methods in evaluating the weights in which experts play a significant role in calculating the weights (Keršuliene et al. 2010). Based on this method, the first and last ranks are assigned to the most and least important criteria, respectively. Finally, the average value of rankings given to each criterion by different experts determines the ranking and importance of that criterion. Therefore, the SWARA method can be useful in cases where the priority of the criteria is specified. The use of the SWARA method, as one of the group decision-making methods, is recommended in critical decision-making situations based on consensus among experts. This method is simple and easy to understand and has fewer paired comparisons compared to the hierarchical analysis and network analysis process methods (Dehnavi et al. 2015). Hence, in the present study, this method was used to calculate the weight of the criteria. Based on this method, in the first step, the criteria are prioritized according to the consensus of the experts. In the second step, the relative importance of the criteria is determined compared to one another. In general, the F-SWARA method has five steps, which are described as follows (Mavi et al. 2017):

Step 1: Determining and sort the project's risks evaluation criteria

Risk assessment criteria are determined in this step, given the factors such as the type and goals of the project, and then the criteria are evaluated in order of importance. The most important criteria are assigned a higher rank and the least important ones are assigned a lower rank.

Step 2: Determining fuzzy expressions and fuzzy numbers

Risk assessment team members should make their judgments about the criteria based on their experience and knowledge. Experts can make this judgment based on a precise numerical value, linguistic expressions, or fuzzy numbers. In many cases, it is difficult for experts to provide numerical values because of uncertainty or lack of quantifiable criteria. Therefore, a linguistic variable or fuzzy number can be used to represent the model. In the proposed model, fuzzy triangular numbers are used for quantitative analysis of the criteria. Linguistic expressions and fuzzy numbers are presented in Table 4.

Table 4. Fuzzy SWARA linguistic expressions and numbers (Mavi et al. 2017).

Linguistic Expressions	Triangular Fuzzy Numbers
Equal importance	(1, 1, 1)
Relatively low importance	(0.67, 1, 1.5)
Low importance	(0.4, 0.5, o.67)
Very low importance	(0.286, 0.33, 0.4)
Extremely little importance	(0.22, 0.25, 0.286)

Step 3: Sort the criteria based on the expected importance of the experts

First, the indicators considered as final by the decision-makers are selected and arranged based on their degree of importance. Accordingly, the most critical indicators are placed in the higher ranks, and the least important indicators are placed in the lower ranks.

Step 4: Get Comparative Importance of the Average Value (S_j) of criterion j from respondents

As shown in Table (4), the relative importance of factor j is higher than that of factor $j-1$, until we reach the last factor. After determining all the relative importance scores cast by the experts, the geometric mean of the respective scores is obtained to integrate their judgment. The output of this step is computing Sj.

Step 5: Calculate the coefficient $\tilde{k}_j$ for each criterion using Eq. (2):

$$\tilde{k}_j = \begin{cases} \tilde{1} & j = 1 \\ \tilde{s}_j + \tilde{1} & j > 1 \end{cases} . \quad (2)$$

Step 6: Determine the recalculated weighting factors $\tilde{q}_j$ value using Eq. (3):

$$\tilde{q}_j = \begin{cases} \tilde{1} & j = 1 \\ \dfrac{\tilde{x}_{j-1}}{\tilde{k}_j} & j > 1 \end{cases} . \quad (3)$$

Step 7: The weights of the criteria are calculated using Eq. (4):

$$\tilde{w}_j = \frac{\tilde{q}_j}{\sum_{k=1}^{n} \tilde{q}_k}, \quad (4)$$

where $\tilde{w}_j$ represents the relative weights of the criterion, and n represents the criteria number.

F-WASPAS Method

Multi-criteria support systems can be used successfully for complex decisions when different options are considered on several criteria. Different studies have discussed the choice of multi-criteria decision-making methods based on different parameters (Ginevičius 2011). One of the parameters that can be considered in selecting a multi-criteria decision-making method is the accuracy of the model. Also, the researchers suggest that combining the two models can improve their accuracy. The accuracy of the results of multivariate decision-making models of the weighted sum model and the weighted multiplication model is relatively good. Hence, the combination of the two models offers high accuracy in decision-making. Also, various researchers have analyzed the accuracy of hybrid models, the results of which emphasize that the accuracy of hybrid models is much higher than that of the accuracy of the models individually (Zavadskas et al. 2012). The WASPAS is considered as one of these hybrid models, which can be highly efficient and accurate in complex decision-making problems. It is worth mentioning that the weighted sum model (WSM) is one of the best and well-known decision-making models in solving multi-criteria problems. In general, the fuzzy WASPAS method has six steps, which are described below (Rani et al. 2020):

Step 1: Normalizing the fuzzy decision matrix

In this step, first, the fuzzy decision matrix is formed. The decision matrix involves an option criterion matrix where the criteria are in the column, and the options are in the row, and the purpose is to rank the research options. This decision matrix is then scored based on the different fuzzy spectra of Table 5. The five fuzzy spectra can be referred to as the famous spectra. Following this step, the decision matrix should be normalized. Normalization occurs through the following two equations: if the criterion has a positive aspect, the first equation is used for normalization, and if the criterion is negative, the second equation is used (Turskis et al. 2015).

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1j} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{i1} & \cdots & \tilde{x}_{ij} & \cdots & \tilde{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mj} & \cdots & \tilde{x}_{mn} \end{bmatrix}; \quad i = \overline{1,m}, \quad j = \overline{1,n}. \quad (5)$$

For negative criteria

$$\tilde{\tilde{x}}_{ij} = \frac{\tilde{x}_{ij}}{max_i \tilde{x}_{ij}}. \quad (6)$$

And for positive criteria

$$\tilde{\tilde{x}}_{ij} = \frac{min_i \tilde{x}_{ij}}{\tilde{x}_{ij}}. \quad (7)$$

Table 5. Verbal expressions and corresponding fuzzy numbers for ranking options (Patil and Kant 2014).

Priorities	Priorities Fuzzy Equivalent
Very weak	(1, 1, 1)
Weak	(1,3,5)
Average	(3,5,7)
Good	(5, 7, 9)
Very good	(7, 9, 11)

Step 3: Calculating values of the optimality function according to the Weighted Sum Model (WSM) for each option

The weighted sum model matrix is obtained by multiplying the standard weight by the normal matrix, according to Eq. (8):

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{\tilde{x}}_{ij} \tilde{w}_j \ , i = \overline{1,m}, \quad (8)$$

where $\tilde{w}_j$ is the weight of j criteria.

Step 4: Calculating values of the optimality function according to the Weighted Product Model (WPM) for each option

The weighted multiplication matrix is derived from the normal fuzzy matrix elements to the fuzzy weight power, according to Eq. (9):

$$\tilde{P}_i = \prod_{j=1}^{n} \left(\tilde{\bar{x}}_{ij}\right)^{\tilde{w}_j}, \quad i = \overline{1, m}. \tag{9}$$

Step 5: The obtained numbers are defuzzified (defuzzification can be done by averaging the fuzzy number elements).

Step 6: The integrated utility function value of the F-WASPAS for each option

The integrated utility function value of the F-WASPAS for each option could be defined as follows:

$$k_i = \lambda \sum_{j=1}^{n} \tilde{Q}_i + (1-\lambda) \sum_{j=1}^{n} \tilde{P}_i, \lambda = 0, \ldots, 1, \ 0 \le k_i \le 1. \tag{10}$$

Based on k_i values of options are ranked according to increasing value. λ is the aggregation coefficient of decision- making accuracy. It is developed to enhance the accuracy of the F-WASPAS method. F-WASPAS method is converted to WPM and WSM when the value of λ is 0 and 1, respectively (Rani et al. 2020). Based on the results of research by Badalpur and Nurbakhsh (2019) emphasized that the accuracy of integrated methods is much higher than that of the accuracy of the models individually.

THE PROPOSED HYBRID APPROACH TO IMPROVE RISK EVALUATION

As described in the introduction section, the FMEA method has major violations. For this reason, a hybrid approach for evaluation and improving risk modes is proposed to obviate these major violations and make the analysis more efficient and effective. The model involves six main steps as follows:

- **Forming an evaluation team and extracting a list of important risks in construction projects**

In the first step for an extracting a list of the important risks in a construction project, an evaluation team consisting of a team of experts is formed and then a complete set of possible risks is extracted from a literature review and interviews with a group of experts. Accordingly, the major risks are considered as options in the hybrid approach.

- **Characterizing respective set of evaluation criteria**

After identifying risks, concerning the FMEA model, three evaluation criteria (risk factors) have been employed as the most critical factors to evaluate above-mentioned risks as follows:

- ➢ Severity (S),
- ➢ Detection (D),
- ➢ Occurrence (O).

- **Determining the scale of risk factor assessment for the traditional FMEA method**

Since the purpose of this article is to show the ability of the proposed hybrid approach to the traditional FMEA model. Therefore, first, the team members were asked to express their views on each of the failure modes versus risk parameters (O, S, and D) in a traditional FMEA model (using a 10-point evaluation scale for variables (See Table (1), (2), and (3)).

- **Calculating of the RPN value for traditional evaluation FMEA model**

At this step, the RPN is used to determining the prioritization of failure modes. The RPN is identified as the multiplication of the three parameters O, S, and D for each risk.

- **Calculating of** the **criteria weights using F-SWARA**

The weights of the three evaluation criteria are calculated by applying F-SWARA proposed in the 'F-SWARA' section.

- **Evaluating and identify of construction project risks using F-WASPAS**

In this step, to identify and evaluate critical risks, the fuzzy WASPAS method proposed in the 'F-WASPAS' section is utilized.

Fig. 1 displays a schematic plan of the procedures to the hybrid MCDM approach, and a combination of the fuzzy SWARA with the Fuzzy WASPAS.

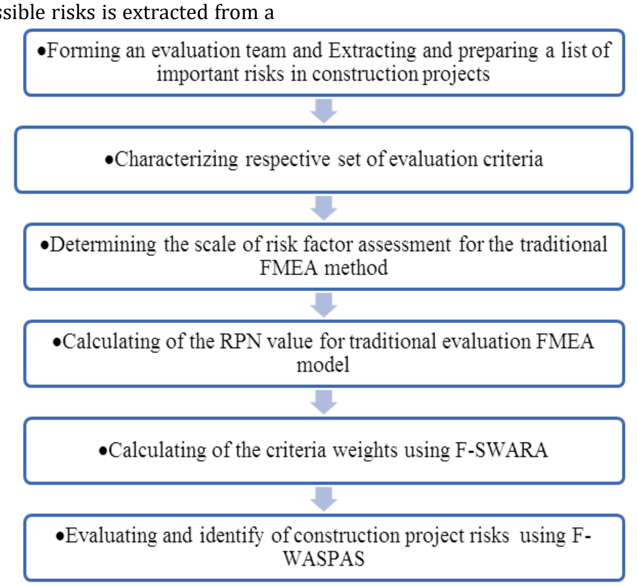

Fig. 1. Proposed model for improving risk evaluation in FMEA.

CASE STUDY: APPLICATION OF THE PROPOSED HYBRID APPROACH BASED FMEA MODEL TO AN IRANIAN CONSTRUCTION PROJECT

In this section, the results of risk assessment and prioritization in a real case were implemented in the Road and Urban Development Organization at Markazi Province. The mentioned organization has considerable experience in road construction, steel structures construction, large structures, and design and construction of manufacturing companies. The case study of the Road and Urban Development Organization was investigated in a 7-story building in Sardar Square called Arak Central Library. Also, the present project covers an area of 6800 square meters and the foundation of 18500 square meters, and this project was about 40% of the physical progress of the structure when collecting data. Accordingly, given the importance of the project, the data collection process involves two major steps:

Step 1: Collecting the numerical data needed to identify the risks and determine the major risks. To obtain information from the first group of experts, a specialized questionnaire was developed and distributed among 12 experts in the field of construction management.

Step 2: During the second step, after identifying the risks, unlike the first step, it was necessary to distribute the questionnaires among the experts working on the project, because the mentioned information was system inputs for project risk assessment and prioritization, and the manager and expert in question need to know enough about the project's conditions. The statistical population distribution involves three employer teams (owner, employer representative, and project manager), two people from advisory teams (design team supervisor and manager), and two people from contractor teams (managing director and worker supervisor). To assess the project risk from the risk assessment, the views of the different teams involved in the project as well as averaging the information for the employer, contractor and consulting engineer were done. The following steps are the results considered for conducting the research:

Extracting a list of important risks in construction projects

To identify project risks, the related risks were detected through numerous interviews and brainstorming sessions with the experts [1, 3, 33, 34]. In the next step, among the detected risks, 23 key risks were selected as available options for measuring and prioritizing the hybrid approach using the primary approaches and expert opinions. These risks are coded with FM 1 through FM 23, as presented in Table 6.

Table 6. Important risks in construction projects.

Risk Code	Risk Description
FM 1	**Requirements**
FM 2	**Uncertainty in the rate of inflation and price growth**
FM 3	**Low performance of the human resources**
FM 4	**Change of employer orders during construction**
FM 5	**Complexity**
FM 6	**Lack of human resources (skilled and unskilled)**
FM 7	**Lack of coordination of project-related human resources**
FM 8	**Insufficient design team experience**
FM 9	**Conflicting investigations on conflict and dispute settlement**
FM 10	**Claims of contractors and contracting companies**
FM 11	**Incompatibility of architectural design with structural design (contractor performs wrong methods of construction)**
FM 12	**Communication and cooperation of a poor contractor with another group**
FM 13	**Lack of coordination, prioritization and careful consideration of multiple contractor projects**
FM 14	**Ambiguity in the description of duties and responsibilities**
FM 15	**Lack of communication between contractor and project management and control**
FM 16	**Inappropriate contractual terms and conditions set by the contractor**
FM 17	**Poor technical skills of contractor staff and being unfamiliar with building codes and safety regulations**
FM 18	**Major disagreement with employer and contractor**
FM 19	**Lack of proper management by the contractor regarding financial matters, supplier support, and subcontractors**
FM 20	**Uncertainty in estimating project quality requirements**
FM 21	**Insufficient consultant experience**
FM 22	**Inconsistency between contractors' schedule for project execution**
FM 23	**Inappropriate coordination with other companies and organizations**

Characterizing respective set of evaluation criteria with FMEA model

In most of the researches in which the FMEA method is used to identify risks, the criteria comprising S, D, and O are used (Fattahi and Khalilzadeh 2018; Rahimi et al. 2018; Tian et al. 2018; Boral et al. 2020).

Calculating of the RPN value for traditional evaluation FMEA model

After forming the evaluation team, extracting a list of important risks in construction projects, and determining risk factors by members of the evaluation team, they were asked to give their opinions on the importance of risk factors (O, S, and D) and failure modes (important risks) for evaluation traditional FMEA model. The results of the RPN calculation are shown in Table (12).

Calculating of the criteria weights using F-SWARA

After identifying important research risks, the weighting of the decision criteria (O, S, and D) is carried out step-by-step based on expert opinion according to the above-mentioned steps. As observed in Table (7), based on the first step of the F-SWARA method, the expert is asked to arrange the criteria in the order of importance; priority is shown in the second column of the table. Also, the second to fifth steps of the F-SWARA method can be observed in columns three and four, respectively. Finally, by considering the steps of the F-SWARA method and weighting normalization, their final weight is shown in column five.

Based on the results of weighting by the experts, it was found that the risk severity index possesses higher priority than the risk occurrence

ISSN- 2394-5125 Vol 7, Issue 1, 2020

and risk detection indices, indicating the importance of the issue to experts.

Table 7. Weight of criteria

Criteria Code	S_j	Kj	Qj	Wj
S	-	(1, 1, 1)	(1, 1, 1)	0.47
O	(0.355, 0.451, 0.602)	(1.355, 1.451, 1.062)	(0.624, 0.689, 0.738)	0.322
D	(0.384, 0.511, 0.704)	(1.384, 1.511, 1.704)	(0.366, 0.456, 0.534)	0.214

Evaluating and identify of construction project risks using F-WASPAS

In this study, the fuzzy WASPAS method, as one of the most precise methods for measuring and prioritizing, is used to rank important risks. Accordingly, based on the above explanation, at first, a decision matrix is formed. The matrix involves rows and columns, with columns assigned to the criteria and rows allotted to research options. Each cell is used to evaluate an option based on a single criterion. The decision matrix is completed by seven experts and is subsequently merged with the arithmetic mean method, as shown in Table (8) (See appendix 1). Then, the decision matrix is normalized based on Eq. (5). In this study, the O and S criteria have a positive aspect, while the D criterion has a negative aspect. The normal matrix is given in Table (9).

Table 9. Fuzzy WASPAS normal matrix

Risk Code	S	O	D
FM 1	(0.425, 0.616, 0.808)	(0.478, 0.681, 0.884)	(0.22, 0.289, 0.419)
FM 2	(0.425, 0.644, 0.836)	(0.449, 0.625, 0.855)	(0.288, 0.302, 0.448)
FM 3	(0.616, 0.808, 1)	(0.594, 0.797, 1)	(0.265, 0.371, 0.619)
FM 4	(0.315, 0.479, 0.671)	(0.275, 0.449, 0.652)	(0.333, 0.52, 0.765)
FM 5	(0.288, 0.452, 0.644)	(0.304, 0.478, 0.681)	(0.213, 0.277, 0.394)
FM 6	(0.452, 0.644, 0.836)	(0.507, 0.710, 0.913)	(0.22, 0.289, 0.419)
FM 7	(0.534, 0.726, 0.918)	(0.565, 0.768, 0.971)	(0.22, 0.289, 0.419)
FM 8	(0.507, 0.699, 0.89)	(0.362, 0.536, 0.739)	(0.213, 0.277, 0.394)
FM 9	(0.397, 0.589, 0.781)	(0.333, 0.507, 0.71)	(0.245, 0.333, 0.52)
FM 10	(0.534, 0.724, 0.918)	(0.565, 0.768, 0.971)	(0.213, 0.277, 0.394)
FM 11	(0.37, 0.562, 0.753)	(0.246, 0.42, 0.623)	(0.22, 0.289, 0.419)
FM 12	(0.479, 0.671, 0.836)	(0.536, 0.739, 0.942)	(0.289, 0.419, 0.765)
FM 13	(0.37, 0.562, 0.753)	(0.507, 0.71, 0.913)	(0.22, 0.289, 0.419)
FM 14	(0.397, 0.589, 0.781)	(0.478, 0.681, 0.884)	(0.265, 0.371, 0.619)
FM 15	(0.397, 0.589, 0.781)	(0.333, 0.536, 0.739)	(0.236, 0.317, 0.481)
FM 16	(0.452, 0.644, 0.836)	(0.507, 0.710, 0.913)	(0.228, 0.302, 0.448)
FM 17	(0.397, 0.589, 0.781)	(0.304, 0.507, 0.71)	(0.255, 0.351, 0.565)
FM 18	(0.452, 0.644, 0.836)	(0.391, 0.594, 0.797)	(0.206, 0.265, 0.371)
FM 19	(0.562, 0.753, 0.945)	(0.391, 0.594, 0.797)	(0.317, 0.481, 1)
FM 20	(0.452, 0.644, 0.836)	(0.478, 0.681, 0.884)	(0.255, 0.351, 0.565)
FM 21	(0.332, 0.504, 0.657)	(0.284, 0.551, 0.801)	(0.267, 0.406, 0.518)
FM 22	(0.408, 0.597, 0.791)	(0.24, 0.478, 0.807)	(0.233, 0.328, 0.529)
FM 23	(0.438, 0.534, 0.727)	(0.33, 0.695, 0.909)	(0.229, 0.266, 0.415)

Then, WSM (Q) and WPS (P) are calculated using equations (8) and (9). Subsequently, the values are defuzzified, as shown in Table (10).

Table 10. WSM and WPM values.

Risk code	P	Q	Definite Q	Definite P
FM 1	(0.363, 0.577, 0.856)	(0.335, 0.55, 0.777)	0.599	0.554
FM 2	(0.359, 0.575, 0.86)	(0.335, 0.552, 0.781)	0.598	0.556
FM 3	(0.474, 0.71, 1.039)	(0.451, 0.681, 0.926)	0.741	0.686
FM 4	(0.262, 0.474, 0.781)	(0.254, 0.473, 0.711)	0.506	0.479
FM 5	(0.247, 0.427, 0.687)	(0.229, 0.418, 0.644)	0.454	0.430
FM 6	(0.383, 0.599, 0.881)	(0.353, 0.568, 0.795)	0.621	0.572
FM 7	(0.431, 0.653, 0.941)	(0.397, 0.613, 0.838)	0.675	0.616
FM 8	(0.333, 0.533, 0.807)	(0.308, 0.507, 0.73)	0.558	0.515
FM 9	(0.295, 0.497, 0.786)	(0.281, 0.487, 0.723)	0.526	0.497
FM 10	(0.43, 0.65, 0.934)	(0.393, 0.607, 0.83)	0.671	0.610
FM 11	(0.246, 0.438, 0.705)	(0.228, 0.426, 0.653)	0.463	0.436
FM 12	(0.414, 0.649, 0.998)	(0.399, 0.635, 0.896)	0.687	0.643
FM 13	(0.36, 0.573, 0.85)	(0.328, 0.544, 0.773)	0.595	0.548
FM 14	(0.362, 0.586, 0.9)	(0.344, 0.571, 0.819)	0.616	0.578
FM 15	(0.294, 0.507, 0.79)	(0.278, 0.494, 0.727)	0.530	0.500
FM 16	(0.384, 0.602, 0.889)	(0.356, 0.574, 0.803)	0.625	0.578
FM	(0.284, 0.5, 0.798)	(0.271, 0.492, 0.733)	0.527	0.499

17				
FM 18	(0.33, 0.54, 0.81)	(0.305, 0.514, 0.734)	0.560	0.518
FM 19	(0.378, 0.621, 1.019)	(0.37, 0.613, 0.891)	0.673	0.625
FM 20	(0.376, 0.599, 0.905)	(0.357, 0.581, 0.822)	0.627	0.587
FM 21	(0.259, 0.505, 0.785)	(0.248, 0.501, 0.727)	0.516	0.492
FM 22	(0.255, 0.484, 0.841)	(0.237, 0.474, 0.77)	0.527	0.494
FM 23	(0.303, 0.552, 0.837)	(0.284, 0.521, 0.762)	0.564	0.522

After defuzzifying the values, the rank of each option is calculated by the Eq. (10), as shown in Table (11). Accordingly, FM3 is ranked first.

Table 11. The rank of each option and their ranking.

Risk code	K	Normal K	Rank
FM 1	0.575	0.0443	11
FM 2	0.576	0.0444	10
FM 3	0.712	0.0549	1
FM 4	0.492	0.0379	21
FM 5	0.442	0.0340	23
FM 6	0.596	0.0459	9
FM 7	0.644	0.0496	4
FM 8	0.536	0.0413	15
FM 9	0.511	0.0394	18
FM 10	0.640	0.0493	5
FM 11	0.449	0.0346	22
FM 12	0.665	0.0512	2
FM 13	0.571	0.0440	12
FM 14	0.596	0.0459	8
FM 15	0.514	0.0396	16
FM 16	0.601	0.0463	7
FM 17	0.513	0.0395	17
FM 18	0.538	0.0414	14
FM 19	0.648	0.0499	3
FM 20	0.606	0.04670	6
FM 21	0.504	0.0388	20
FM 22	0.510	0.0393	19
FM 23	0.542	0.0418	13

DISCUSSION

The present study aimed to present a novel hybrid approach to evaluate the risks of construction projects. Accordingly, the types of risks involved in construction projects were identified, which ultimately improved the results of the traditional FMEA method. A combination of several MCDM methods, including the SWARA and WASPAS methods, was proposed based on the traditional FMEA method in the fuzzy environment. Subsequently, the proposed method was applied to the Arak Central Library construction project, and the validity of the findings was examined concerning the following aspects:

- To illustrate the effectiveness of the proposed approach, the traditional RPN method based on study of the Rahimi et al. (2018), and the novel hybrid approach in the fuzzy environment are implemented in a case study. Table (12) indicates the results of multiple risk rankings using the novel hybrid approach and the traditional RPN method. As shown, the proposed model is superior to other methods. First, it shows that there is a significant difference between the rankings offered by the two traditional approaches and the proposed approach. The reason for these inconsistent rankings is mainly related to the relative importance of the parameters S, O, and D in calculating the RPN and weight of the criteria in which changes in the rankings presented for the risk states were not considered in the traditional ranking. Also, in a typical RPN, different sets of O, S, and D may have the same RPN value, but differ in the ranking by the proposed model. Accordingly, given this deep gap, the novel hybrid approach can solve this problem by providing accurate rankings for each risk and distinguishing the results well.

Table 12. Comparing the rankings

Risk Code	Risk Description	Hybrid Approach Ranking	Traditional Ranking of the FMEA Method
FM 1	Requirements	11	9
FM 2	Uncertainty in the rate of inflation and price growth	10	9
FM 3	Low performance of the human resources	1	1
FM 4	Change of employer orders during construction	21	18
FM 5	Complexity	23	17
FM 6	Lack of human resources (skilled and unskilled)	9	8
FM 7	Lack of coordination of project-related human resources	4	4
FM 8	Insufficient design team experience	15	12
FM 9	Conflicting investigations on conflict and dispute settlement	18	15
FM 10	Claims of contractors and contracting companies	5	5
FM 11	Incompatibility of architectural design with structural design (contractor performs wrong methods of construction)	22	15
FM 12	Communication and cooperation of a poor contractor with another group	2	2
FM	Lack of coordination,	12	10

13	prioritization and careful consideration of multiple contractor projects		
FM 14	Ambiguity in the description of duties and responsibilities	8	8
FM 15	Lack of communication between contractor and project management and control	16	16
FM 16	Inappropriate contractual terms and conditions set by the contractor	7	6
FM 17	Poor technical skills of contractor staff and being unfamiliar with building codes and safety regulations	17	13
FM 18	Major disagreement with the employer and contractor	14	11
FM 19	Lack of proper management by the contractor regarding financial matters, supplier support, and subcontractors	3	3
FM 20	Uncertainty in estimating project quality requirements	6	7
FM 21	Insufficient consultant experience	20	17
FM 22	Inconsistency between contractors' schedule for project execution	19	14
FM 23	Inappropriate coordination with other companies and organizations	13	11

- By comparing the results of the above methods (see Table (12)), combining SWARA and WASPAS methods based on the FMEA method in the fuzzy environment can be used to improve the risk assessment and prioritization of construction projects. The results presented in Table (12) indicate that the highest risk mode is still FM 3, despite some differences in ranking risk modes, which confirms the results obtained from the proposed approach. The proposed hybrid approach allows us to detect the root causes of some construction project failures, to achieve the main objectives of the project, and to examine the risk assessment problem more appropriately and accurately.
- Spirman correlation coefficient was used to validate the results of the proposed hybrid approach in risk evaluation of the construction project. According to the calculations, the correlation coefficient value between the prioritization results of the two proposed hybrid and traditional approaches was obtained 0.977, which can be concluded that there was a high correlation between the proposed ranking and the traditional model and the proposed method was very stable. The traditional FMEA method is a fundamental step.

CONCLUSION

construction project managers and systems face a variety of risks and neglecting and failing to manage them properly result in delays, cost overruns, and failure to meet project quality and safety requirements. Many of these consequences can be avoided by adopting an appropriate scientific approach to risk assessment. Accordingly, given the importance of risk assessment and prioritization based on the traditional FMEA approach, a novel hybrid approach was presented for the risk assessment of construction projects in the fuzzy environment. The proposed approach involves combining multivariate decision-making methods with fuzzy WASPAS based on the FMEA technique to assess and detect the risks of construction projects. In the hybrid approach, the fuzzy SWARA method was used to determine the relative importance of the parameters S, O, and D in calculating the weight of the criteria, and the fuzzy WASPAS method to prioritize the detected risks. In addition to solving the typical RPN problems, the proposed approach can take advantage of two novel multi-criteria decision-making methods in the fuzzy environment to improve the risk assessment of the construction project. Furthermore, the present case study validates that the proposed model is an effective and efficient risk assessment tool for prioritizing risk modes in FMEA for further corrective actions. By using the proposed hybrid approach, we attempted to introduce a method for providing appropriate analyses to project managers by detecting substantial risks in risk management decision-making and determining significant risks. Finally, an appropriate framework was provided to improve the risk assessment of construction projects via FMEA and to provide guidance for risk analysis in other projects and industries.

ACKNOWLEDGMENT

This paper was extracted from the Arak Central Library Building Project that was executed and implemented by the Road and Urban Development Organization of the Markazi Province of Iran.

Funding

This study was funded by the Road and Urban Development Organization of the Markazi Province, Iran

Conflict of Interest

No potential conflict of interest was reported by the authors.

REFERENCES

1. Ardeshir, A., Amiri, M., Mohajeri, M. "Safety Risk Assessment in Mass Housing Projects Using Combination of Fuzzy FMEA, Fuzzy FTA and AHP-DEA", Iran Occupational Health Journal, 10(6), pp. 78-91, 2013. http://ioh.iums.ac.ir/article-1-883-en.html
2. Badalpur M, Nurbakhsh E. 2019. An application of WASPAS method in risk qualitative analysis: a case study of a road construction project in Iran. International Journal of Construction Management.1-9.
3. Bonato J, Badurina M, Dobrinić J. 2018. Parameters Assessment of the FMEA Method by Means of Fuzzy Logic. Pomorski zbornik.(2):123-132.
4. Boral S, Howard I, Chaturvedi SK, McKee K, Naikan V. 2020. An integrated approach for fuzzy failure modes and effects analysis using fuzzy AHP and fuzzy MAIRCA. Engineering Failure Analysis. 108:104195.
5. Chapman C, Ward S. 1996. Project risk management: processes, techniques and insights. John Wiley.
6. Dehnavi A, Aghdam IN, Pradhan B, Varzandeh MHM. 2015. A new hybrid model using step-wise weight assessment ratio analysis (SWARA) technique and adaptive neuro-fuzzy inference system (ANFIS) for regional landslide hazard assessment in Iran. Catena. 135:122-148.
7. Fattahi R, Khalilzadeh M. 2018. Risk evaluation using a novel hybrid method based on FMEA, extended MULTIMOORA, and AHP methods under fuzzy environment. Safety science. 102:290-300.

8. Hosseinzadeh M, Gheidar Khaljani J. 2013. A review of methods for detecting product design risks. Standard management and quality.
9. Ilbahar E, Karaşan A, Cebi S, Kahraman C. 2018. A novel approach to risk assessment for occupational health and safety using Pythagorean fuzzy AHP & fuzzy inference system. Safety science. 103:124-136.
10. Keršuliene V, Zavadskas EK, Turskis Z. 2010. Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). Journal of business economics and management. 11(2):243-258.
11. Kutlu AC, Ekmekçioğlu M. 2012. Fuzzy failure modes and effects analysis by using fuzzy TOPSIS-based fuzzy AHP. Expert Systems with Applications. 39(1):61-67.
12. Liu, H.-C., Liu, L., Liu, N. "Risk evaluation approaches in failure mode and effects analysis: A literature review", Expert Systems with Applications, 40(2), pp. 828-838, 2013. https://doi.org/10.1016/j.eswa.2012.08.010
13. Liu H-C. 2016. FMEA using uncertainty theories and MCDM methods. FMEA using uncertainty theories and MCDM methods. Springer; p. 13-27.
14. Liu H-C, You J-X, Ding X-F, Su Q. 2015. Improving risk evaluation in FMEA with a hybrid multiple criteria decision making method. International Journal of Quality & Reliability Management.
15. Mardani A, Nilashi M, Zakuan N, Loganathan N, Soheilirad S, Saman MZM, Ibrahim O. 2017. A systematic review and meta-Analysis of SWARA and WASPAS methods: Theory and applications with recent fuzzy developments. Applied Soft Computing. 57:265-292.
16. Mavi RK, Goh M, Zarbakhshnia N. 2017. Sustainable third-party reverse logistic provider selection with fuzzy SWARA and fuzzy MOORA in plastic industry. The International Journal of Advanced Manufacturing Technology. 91(5-8):2401-2418.
17. Miler J. 2005. A method of software project risk identyfication and analysis.
18. Omidvar M, Nirumand F. 2017. Risk assessment using FMEA method and on the basis of MCDM, fuzzy logic and grey theory: A case study of overhead cranes. Health and Safety at Work. 7(1):63-76.
19. Patil SK, Kant R. 2014. A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers. Expert systems with applications. 41(2):679-693.
20. Rahimi Y, Tavakkoli-Moghaddam R, Iranmanesh SH, Vaez-Alaei M. 2018. Hybrid approach to construction project risk management with simultaneous FMEA/ISO 31000/evolutionary algorithms: Empirical optimization study. Journal of Construction Engineering and Management. 144(6):04018043.
21. Rani P, Mishra AR, Pardasani KR. 2020. A novel WASPAS approach for multi-criteria physician selection problem with intuitionistic fuzzy type-2 sets. Soft Computing. 24(3):2355-2367.
22. Safari H, Faraji Z, Majidian S. 2016. Identifying and evaluating enterprise architecture risks using FMEA and fuzzy VIKOR. Journal of Intelligent Manufacturing. 27(2):475-486.
23. Stamatis DH. 2003. Failure mode and effect analysis: FMEA from theory to execution. Quality Press.
24. Tian Z-p, Wang J-q, Zhang H-y. 2018. An integrated approach for failure mode and effects analysis based on fuzzy best-worst, relative entropy, and VIKOR methods. Applied Soft Computing. 72:636-646.
25. Vahdani B, Salimi M, Charkhchian M. 2015. A new FMEA method by integrating fuzzy belief structure and TOPSIS to improve risk evaluation process. The International Journal of Advanced Manufacturing Technology. 77(1-4):357-368.
26. Ginevičius, R. "A new determining method for the criteria weights in multicriteria evaluation", International Journal of Information Technology & Decision Making, 10(06), pp. 1067-1095, 2011.
27. https://doi.org/10.1142/S0219622011004713
28. Wideman RM. 1992. Project and program risk management: a guide to managing project risks and opportunities. Univerza v Mariboru, Ekonomsko-poslovna fakulteta.
29. Wehbe, F. A., & Hamzeh, F. R."Failure mode and effect analysis as a tool for risk management in construction planning", 21st Annual Conference of the International Group for Lean Construction, 2013, pp. 685-694.
30. Zavadskas, E. K., Turskis, Z., Antucheviciene, J., Zakarevicius, A. "Optimization of weighted aggregated sum product assessment", Elektronika ir elektrotechnika, 122(6), pp. 3-6, 2012. https://doi.org/10.5755/j01.eee.122.6.1810
31. Zegordi S, Nazari A, Rezaee Nik E. 2014. Project risk assessment by a hybrid approach using fuzzy-anp and fuzzy-topsis. Sharif Journal of Indusrial Engineering and Management. 29(1):3-14.

Appendix 1

Table 8. Fuzzy WASPAS Decision Matrix

Risk Code	S	O	D
FM 1	(4.429, 6.429, 8.429)	(4.714, 6.714, 8.714)	(4.429, 6.429, 8.429)
FM 2	(4.714, 6.714, 8.714)	(4.429, 6.429, 8.429)	(4.143, 6.143, 8.143)
FM 3	(6.429, 8.429, 10.429)	(5.857, 7.857, 9.857)	(3,5,7)
FM 4	(3.286, 5, 7)	(2.714, 4.429, 6.429)	(2.429, 3.571, 5.571)
FM 5	(3, 4.714, 6.714)	(3, 4.714, 6.714)	(4.714, 6.714, 8.714)
FM 6	(4.714, 6.714, 8.714)	(5,7,9)	(4.429, 6.429, 8.429)
FM 7	(5.571, 7.571, 9.571)	(5.571, 7.571, 9.571)	(4.429, 6.429, 8.429)
FM 8	(5.286, 7.286, 9.286)	(3.571, 5.286, 7.286)	(4.714, 6.714, 8.714)
FM 9	(4.143, 6.143, 8.143)	(3.286, 5,7)	(3.571, 5.571, 7.571)
FM 10	(5.571, 7.571, 9.571)	(5.571, 7.571, 9.571)	(4.714, 6.714, 8.714)
FM 11	(3.857, 5.857, 7.857)	(2.429, 4.143, 6.143)	(4.429, 6.429, 8.429)
FM 12	(5,7,9)	(5.286, 7.286, 9.286)	(2.429, 4.429, 6.429)
FM 13	(3.857, 5.857, 7.857)	(5,7,9)	(4.429, 6.429, 8.429)
FM 14	(4.143, 6.143, 8.143)	(4.714, 6,714, 8.714)	(3,5,7)
FM 15	(4.143, 6.143, 8.143)	(3.286, 5.286, 7.286)	(3.857, 5. 857, 7.857)
FM 16	(4.714, 6.714, 8.714)	(5,7,9)	(4,143, 6.143, 8.143)
FM 17	(4.143, 6.143, 8.143)	(3,5,7)	(3.286, 5.286, 7.286)
FM 18	(4.714, 6.714, 8.714)	(3.857, 5.857, 7.857)	(5,7,9)
FM 19	(5.857, 7.857, 9.857)	(3.857, 5,857, 7.857)	(1.857, 3.857, 5.857)
FM 20	(4.714, 6.714, 8.714)	(4.714, 6.714, 8.714)	(3.286, 5.286, 7.286)
FM 21	(3.458, 5.251, 6.855)	(2.799, 5.429, 7.896)	(3.584, 4.578, 6.958)
FM 22	(4.252, 6.225, 8.252)	(2.362, 4.714, 7.959)	(3.512, 5.658, 7.986)
FM 23	(4.571, 5.571, 7.584)	(3.252, 6.854, 8.957)	(4.476, 6.986, 8.125)