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A Novel Multi-Criteria-Based Risk Management Approach for Agile Projects

Saeed Khaji[1,*], Seyed Farid Ghannadpour[1]

[1] Departmant of Industrial Engineering, Iran University of Science & Technology, Tehran, Iran; saeidkhaji@gmail.com; ghannadpour@rail.iust.ac.ir.

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Abstract

One significant factor impacting projects is the neglect of risk management for internal and external risks, which can lead to delays in scheduling, cost overruns, or even complete project failure. This research reviews existing literature to explore the differences between agile and traditional approaches, focusing on short iterations, flexibility, risk response strategies, and team involvement. Additionally, it identifies and categorizes the key risks affecting agile projects into three distinct groups. A team of 13 experts, including academic professors, project managers, and agility specialists, was assembled to facilitate the research. These experts completed a questionnaire regarding 19 selected risks encompassing all relevant aspects. Initially, the risks were ranked using the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) Network Analysis Process (DANP) technique. The final ranking was established by evaluating the results of the DANP method and the probability of occurrence and impact of each risk. The ranking results indicated that the dimension of "common organizational and environmental risks," which encompasses risks related to "types of project delays," "management and consideration of project changes," and "trust among the team and stakeholders," holds greater importance and impact on agile projects compared to other risks.

Keywords: Project risk management, Agile projects, Likelihood and impact matrix, Multi-criteria decision making, Fuzzy decision making, trial and evaluation laboratory network analysis process technique, Fuzzy sets.

1 | Introduction

Today, organizations encounter challenges from intense international competition, rapid technological advancements, and rising customer demands and quality expectations. In this context, effective and efficient management is crucial for organizational success. Recently, project management has emerged as a vital

Corresponding Author: ghannadpour@rail.iust.ac.ir
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approach for executing business activities effectively. Given the current dynamic and competitive landscape, there is a growing emphasis on value engineering and the optimal utilization of resources. In this environment, the one-dimensional approaches to project management of the past have become inadequate. The new strategy that has gained prominence in project management over the last few decades, the agile methodology, has evolved and been developed specifically for software development.

Managing various projects often involves numerous ambiguous and unknown factors, called uncertainties. These uncertainties can impact project outcomes, sometimes positively and other times negatively. To address this, several methodologies and standards have been developed to assist project managers in identifying and measuring these uncertainties. The goal is to minimize negative deviations while maximizing positive outcomes that meet the project's expected objectives.

In recent years, numerous researchers and experts in project management have highlighted that many projects fail due to frequent cost overruns, delays, and poor performance in terms of quality and customer satisfaction. The Project Management Institute (PMI) first documented these common issues in 1969. It can be asserted that the primary factor contributing to delays in project schedules and budget overruns is inadequate risk management. Risk is an inherent aspect of every project, and effective risk management is a fundamental pillar that ensures the objectives outlined in the project charter are met.

This has become increasingly important due to the technical complexities and dynamic conditions of modern projects. Consequently, reducing negative risks and capitalizing on positive risks has become a primary focus for project managers. To effectively implement risk management methods within an agile framework and achieve both qualitative and quantitative goals, it is essential to identify the criteria that influence success. Given the complexities of activities, communication, multiple uncertainties, and high-risk potentials in these projects, these criteria should address technological, managerial, financial, communication, and cultural aspects and capabilities.

This comprehensive understanding will enhance the implementation process. Additionally, designing a system to identify the sources of these risks requires assessing, compiling, and responding to them, as well as establishing monitoring programs to track their progression.

This research aims to address the following questions by employing a team of expert project managers and utilizing a multi-stage research method:

I. What are the differences between traditional risk management and agile risk management?

II. Given the interdependencies between these risks, which type is more critical and impacts a project's success?

This research is applied and field-based, with data collected through questionnaires. Following a review of the literature and identifying research gaps, we first examined the differences between risk management in agile and traditional projects. The methodology developed for this study consists of three main stages of risk management: risk readiness, risk identification, and risk assessment. With the assistance of an expert team, the risks were initially ranked using the fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) Network Analysis Process (DANP) technique. Subsequently, final rankings were calculated by multiplying the likelihood of occurrence by the impact of each risk, based on the results obtained from the fuzzy DANP method.

2 | Literature Review

Risk management in agile projects is a critical aspect of ensuring project success and mitigating potential disruptions. In recent years, the increasing complexity and dynamic nature of agile environments have highlighted the importance of continuous risk identification and response. As agile methodologies emphasize flexibility and iterative progress, effectively managing risks becomes crucial for adapting to frequent changes. This section categorizes related studies into key themes: 1) Risk management in agile, Information Technology (IT), and software development, and 2) Success factors, organizational agility, and industrial risk management

2.1|Risk Management in Agile, Information Technology, and Software Development

This section covers various studies and methodologies focused on risk management strategies in agile and software development environments. It highlights efforts to identify, assess, and prioritize risks through different tools and frameworks. Researchers emphasize the importance of understanding risks, using expert surveys, and applying models like AHP to prioritize mitigation methods, ensuring project success.

Tavares et al. [1] provided a comprehensive analysis of risk management practices in agile projects by examining 129 studies. Using the Analytical Hierarchy Process (AHP) and expert input, they categorized and ranked these practices, offering valuable insights into the prioritization of risk management strategies. In another study, Tavares et al. [2] introduced the Rm4Am tool, specifically designed to manage risks in agile software development.

Their methodology involved ranking 127 risk management methods, classifying them into five main categories and 48 subcategories, and seeking expert consensus to refine this classification. The final findings highlighted nine methods with the most significant impact on project risk reduction. Hammad et al. [3] conducted an online survey with 54 industry experts to identify major risks in agile projects and the strategies employed to mitigate them, finding that project deadlines and changing requirements were among the most significant risks in agile environments.

Singh et al. [4] developed the AGP model based on survey responses from 1,868 professionals across Europe and Asia. Through Exploratory Factor Analysis (EFA) and Cronbach's alpha, they identified four key factors crucial for risk mitigation in IT projects. Meanwhile, Shrivastava and Rathod [5] designed a risk management framework for Disciplined Agile Delivery (DAD) projects, categorizing risks into five domains. Their research applied the Kendall ranking method to assess the impact of these risks, revealing that group awareness, external stakeholder collaboration, and the Software Development Lifecycle (SDLC) had the most influence.

Further expanding on DAD risk management, Shrivastava and Rathod [5] employed a goal-based approach to assess risk factors in relation to project objectives, including time, cost, and quality. Their dual-survey approach helped rank risk factors based on their perceived impact, offering a structured methodology for prioritizing risks in agile projects. Additionally, their earlier work, Shrivastava and Rathod [6], systematically categorized research on DAD risk management, identifying key risk areas within software development processes.

Elzamly et al. [7] surveyed 76 software developers in Palestine, identifying 50 key risks across the SDLC and evaluating 30 risk management techniques, emphasizing the significance of proper IT management, comprehensive project requirement analysis, and user involvement throughout the SDLC as critical risk control measures. Similarly, Charles [8] prioritized software risk factors using the AHP method, categorizing 16 risks into four groups and concluding that financial challenges and task complexity were the most pressing concerns.

Simon and Reicher [9] explored continuous risk management in organizations by analyzing 59 research articles and surveying 181 project managers, identifying obstacles to implementing risk management strategies and highlighting the importance of adaptive risk management for successful project outcomes. A novel approach to risk management training was presented by Annunziata et al. [10], who developed SERGE, a serious game designed to enhance students' risk management skills through gamification, demonstrating that interactive learning tools could effectively improve students' understanding of risk mitigation strategies.

Venczel et al. [11] examined startup risk management through a literature review to identify common causes of startup failures, introducing a two-level risk management framework that combined a risk-oriented model with flexible tools to support startups in managing uncertainties. Sundararajan et al. [12] investigated risk management practices in large-scale agile outsourcing projects using the Scrum methodology. Their case study of four teams identified 66 solutions for mitigating outsourcing risks, later consolidated into nine primary categories based on expert interviews.

2.2 | Success Factors, Organizational Agility, and Industrial Risk Management

This section discusses the key success factors that influence project outcomes and the role of organizational agility and industrial safety in risk management. It explores how agility, response speed, flexibility, and proper management are vital for mitigating risks across various industries, including manufacturing and IT. Researchers also focus on assessing safety risks and identifying critical points to prevent accidents.

Bozorgzad [13] explored the key success factors in agile project management by reviewing literature and refining success indicators through expert surveys, emphasizing speed, responsiveness, and flexibility as the most critical factors in ensuring agile project success. Yaghoubi and Dalirpour [14] analyzed key success factors in project-oriented organizations through factor analysis and DEMATEL, identifying project management, project management offices, and access to new technologies as the most influential factors in project success.

Barghi [15] proposed a hybrid PMBOK-based model for project risk assessment under uncertainty. Using fuzzy Delphi, DEMATEL, and ANP techniques, they identified and ranked 17 critical risk factors from an initial set of 32, highlighting economic and political sanctions, foreign investor attraction, and regional infrastructure deficiencies as the most influential risks. Mahmoud et al. [16] analyzed organizational agility as a risk mitigation strategy using factor analysis and neural networks to classify and evaluate agility capabilities, identifying six primary agility factors: response speed, flexibility, competence, management structure, and product design and production.

Radmankian et al. [17] focused on safety risks in foundry and machine tool workshops, employing fuzzy scoring techniques to assess and prioritize risks, revealing that hazardous events such as tool ejection and molten metal spillage posed the highest threats. Mohamadi et al. [18] further investigated industrial safety risks using field methods and hypothesis testing to identify critical accident-prone points in research settings, finding that spills and projectile incidents involving molten metal were among the most dangerous risks encountered in these environments.

2.3 | Research Gap

Through the content and statistical analysis of the reviewed articles, along with a comparison to risk management standards, the following gaps were identified:

The content analysis revealed that only a limited number of articles addressed all stages of risk management (Risk identification, evaluation, and treatment), while most focused on just a few stages.

A significant research gap found in these articles is that only a handful evaluated the interdependencies among risks, with the majority applying their techniques without considering this crucial aspect.

Additionally, the articles demonstrated a low diversity of decision-making techniques employed in a fuzzy environment.

Finally, the analysis indicated that none of the articles have comprehensively investigated all the essential and influential risks in agile projects. Instead, they prioritized a limited subset of risks, neglecting others only mentioned minimally.

3 | Research Method

3.1 | Comparison of Two Agile and Traditional Approaches

The primary differences between the two approaches are as follows:

I. Short Iterations: A key difference between traditional and agile methodologies is agile's short iterations, enabling frequent, incremental deliverables. This allows for continuous risk assessment and management throughout the project, rather than deferring them to later stages [19].

II. Approach: Traditional project management treats risk management as a distinct phase, typically during planning, following a linear process of identification, assessment, and mitigation. Agile, however, integrates risk management into its iterative process, ensuring risks are identified and reassessed continuously. Techniques such as brainstorming, risk workshops, and stakeholder involvement aid early identification. Agile teams use daily stand-ups and regular reviews to monitor risks, prioritize them using matrices or voting systems, and implement necessary corrective actions [20].

III. Flexibility: Agile projects emphasize adaptability, requiring a dynamic risk management approach. Teams frequently review and adjust strategies based on project changes and new risks. Documenting lessons learned ensures long-term improvements [19].

IV. Risk response strategies: Traditional projects rely on standard risk responses—avoidance, acceptance, transfer, or mitigation. Agile, in contrast, employs preventive and adaptive strategies, addressing risks incrementally by breaking them into smaller components for continuous evaluation and adjustment [19].

V. Team participation: Traditional risk management is often handled by specialists, whereas agile fosters shared responsibility across the team and stakeholders. Open communication, regular meetings, and a culture of transparency enable effective risk identification and mitigation [20].

Agile risk management differs from traditional methods in iterations, approach, flexibility, response strategies, and team involvement. Rooted in adaptability, continuous improvement, and collaboration, it integrates traditional practices to mitigate risks proactively, ensuring project success in a dynamic environment.

3.2 | Research Methodology

This research is conducted in five steps to address key gaps in the field:

I. First, we provide a brief introduction to risk management in agile projects.

II. Next, we identified risks in agile projects using available resources, merging or eliminating similar items to create a comprehensive questionnaire encompassing all relevant risk aspects.

III. Utilizing the data collected from experts via the questionnaire, we ranked the identified risks using the fuzzy DANP method.

IV. We employed a hybrid DANP model, integrating ANP and DEMATEL approaches, to account for the interdependencies among risks.

V. Finally, the risk ranking was performed in a fuzzy environment, allowing us to incorporate verbal variables and uncertainties identified during the study.

Note: To simplify the issue, the likelihood of occurrence and the impact of risks are considered without mutual influence on each other.

Next, according to *Fig. 1*, we will review the steps:

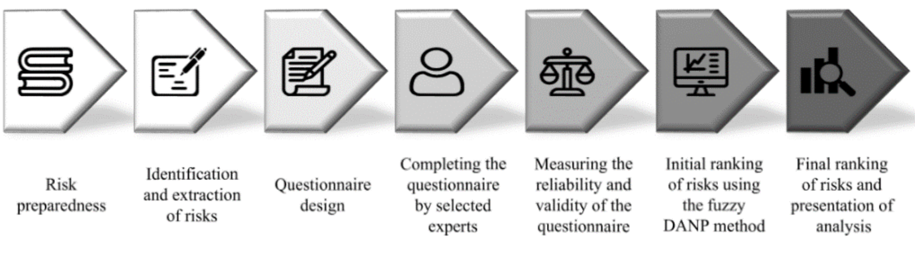

Fig. 1 Research methodology.

3.2.1 | Risk management approach for agile projects

The agile risk management process is illustrated in *Fig. 2*. It begins with defining project goals, followed by identifying potential risk factors and the likelihood of their occurrence. These elements may be reevaluated if significant changes occur within the project. Next, the project context must be established, as the agile process is applied within this specific framework. The unique parameters and conditions of the project heavily influence the appropriate responses to each identified risk. Once the previous steps are completed, the risk scope should be assessed with input from the entire team and key stakeholders.

The subsequent sections will cover risk identification, assessment, and management, including appropriate responses and ongoing monitoring and control. While we often utilize traditional techniques, certain aspects will be adapted to fit the agile methodology.

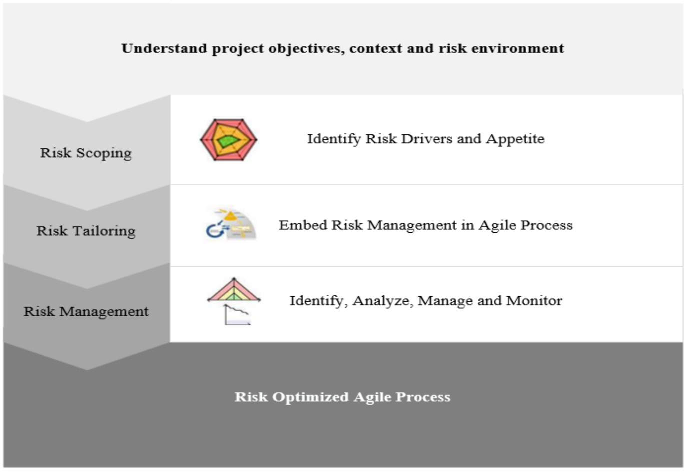

Fig. 2 An overview of the agile risk management process [19].

3.2.2 | Risk readiness

This initial step lays the groundwork for subsequent phases and involves reviewing the literature on various risk identification approaches. A team of experienced experts from different project management departments was assembled to facilitate collaboration.

3.2.3 | Risk identification

Next, through a review of the literature in this field, we identified the key criteria for risk management in agile projects, both directly and indirectly mentioned in various articles. We consolidated these criteria into 19 distinct risks by merging similar ones to ensure comprehensive coverage. Some risks are exclusive to agile projects, such as "management of project changes and attention to them." In contrast, others, like "economic stability," are not unique to agile projects and may be encountered in other projects. However, due to their potential likelihood and impact on project success, these broader risks were also included in the questionnaire.

3.2.4 | Risk ranking

In this step, the risks identified and screened in the previous phase were evaluated and ranked by the designated experts, utilizing the combined fuzzy DANP method for initial ranking. The network analysis process proposed serves as a multi-criteria decision-making method designed to determine the weights of various criteria and select the best options.

However, one limitation of this technique is that it does not account for the complex interrelationships among the criteria. On the other hand, the DEMATEL method was created to solve complex problems, the purpose of which is to identify the mutual relationships between the criteria, and the advantage of this method is the clarity and transparency between the criteria.

The DANP method, which combines the advantages of the ANP and DEMATEL approaches, is used for this purpose. For the final ranking of risks, the values derived from the DANP method were multiplied by the likelihood of occurrence and the severity of impact for each risk. This calculation yielded the final rankings. However, it's important to note that the values obtained for the probability and severity of each risk simplify the problem by not fully accounting for the dependencies and interactions among the risks.

3.4 | Fuzzy DEMATEL Network Analysis Process Method

This method is one of the types of multi-criteria decision-making techniques, which has been of great interest in recent years due to its features. This method was developed in 2008 by combining DEMATEL and ANP techniques.

The ANP technique was created to deal with the interactions between the evaluated criteria in different problems this method was an extension of the AHP method, which accepts and examines the assumption of the existence of relationships between the criteria that this method forms pairwise comparison matrices to calculate the relationships between criteria and model components and calculates the vectors corresponding to each of the pairwise comparison matrices and puts them in a supermatrix and solves the model, This issue when we intend to examine the relationships between many criteria, will cause the formation of a large number of pairwise comparison matrices, which leads to complexity and spending a lot of time on the problem.

To solve the problem stated above, we use the DEMATEL method, which, compared to ANP, requires fewer paired matrices to calculate the internal relationship between the criteria, which reduces the complexity and reduces the calculations. We also know that the DEMATEL method cannot form a supermatrix and rank the examined options, while the ANP method has this ability.

So, taking into account the advantages and limitations of the two techniques mentioned above, we combine the two methods and use the combined DANP method to cover the limitations of the mentioned techniques and get the advantages of both.

Step 1. Formation of direct relationship matrix (D). In this step, the target experts were asked to declare in the form of a questionnaire, the degree of influence of the ith risk on the jth risk using numbers that show verbal and definite expressions. Then these verbal expressions will be converted into their fuzzy number equivalent according to the membership function table presented in *Table 1*.

Table 1. Membership function table.

Verbal Expression	Definitive Equivalent	Fuzzy Equivalent
No impact	0	(0.0,0.1,0.3)
low impact	1	(0.1,0.3,0.5)
Medium impact	2	(0.3,0.5,0.7)
Significant impact	3	(0.5,0.7,0.9)
Very significant impact	4	(0.7,0.9,1.0)

Finally, according to the experts' opinion, the average is taken according to *Formula 5*. We form the direct relationship matrix between the risks in the order of the screened risks in the row and column.

$$\tilde{z} = \frac{\tilde{x}_1 \oplus \tilde{x}_2 \oplus \ldots \oplus \tilde{x}_K}{K}. \quad (1)$$

$\tilde{x}_K = (l_{ij}, m_{ij}, n_{ij})$ →A fuzzy number of Kth expert's opinions shows the influence of the ith criterion on the j^{th} criterion.

K = The number of experts

Step 2. Calculate the normalized direct-relationship matrix. In this step, we normalize the direct relationship matrix obtained in the previous step by using *Eq. (6)* and dividing all its terms by the parameter r, where n'_{ij} is the third component of the interpolated fuzzy number.

$$r = \max(\sum_{j=1}^{n} n'_{ij}. \tag{2}$$

Step 3. Forming the total relationship matrix of criteria (T_C). After calculating the above matrices, we get the fuzzy relationship matrix using *Formulas (7)-(10)*. Note that each row of this numerical matrix is in the form of $\tilde{t} = (l_{ij}^{t}, m_{ij}^{t}, n_{ij}^{t})$.

We obtain each range of fuzzy numbers according to the following relations:

$$\tilde{T} = \lim_{k \to +\infty} (\tilde{H}_1 \oplus \tilde{H}_2 \bigoplus \ldots \oplus \tilde{H}_k). \tag{3}$$

$$[l_{ij}^{t}] = H_l \times (I - H_l)^{-1}. \tag{4}$$

$$[m_{ij}^{t}] = H_m \times (I - H_m)^{-1}. \tag{5}$$

$$[n_{ij}^{t}] = H_n \times (I - H_n)^{-1}. \tag{6}$$

Step 4. Calculating the total relationship matrix of dimensions (T_D). In this step, we obtain the T_D matrix from the total relationship matrix of criteria (T_C). If we consider each dimension of the matrix T_D as t_{ij}, each t''_{ij} is obtained from the average measures of T_C^{ij} it is related to each of the dimensions.

Step 5. Calculate the intensity of influence and direction of influence. According to *Formulas (11)* and *(12)*, we calculated the indices r_i and d_j, where r_i shows the sum of the ith row and d_j shows the sum of the jth column of the T_C matrix according to the relevant dimension.

In the same way, R_i and D_j have been calculated for the T_D matrix, where the R_i index shows the sum of the ith row and the D_j index shows the jth column sum of the T_D matrix. In the following, to draw and analyze the graph, we need 2 indicators of intensity of influence and direction of influence, which are obtained by using r_i and d_j, which we will have for each i=j:

$$(\tilde{D}_j)_{n\times 1} = \left[\sum_{j=1}^{n} \tilde{T}_{ij}\right]_{n\times 1}. \tag{7}$$

$$(\tilde{R}_i)_{1\times n} = \left[\sum_{i=1}^{n} \tilde{T}_{ij}\right]_{1\times n}, \tag{8}$$

Where $\tilde{D}_j$ and $\tilde{R}_i$ are 1×n and 1×n matrix.

In the next step, we deal with the importance of indicators ($\tilde{D}_j+\tilde{R}_i$) and the relationship between criteria ($\tilde{D}_j$-$\tilde{R}_i$). If $\tilde{D}_j$-$\tilde{R}_i$>0, the relevant criterion is influences, and if $\tilde{D}_j$-$\tilde{R}_i$<0, the relevant criterion is influenced. In the following, we will calculate the intensity of influence index for each of the T_C and T_D matrices (*Table 2*) and then defuzzified the obtained values.

Table 2. Intensity and direction of influence.

Criterion	Calculation Method	Explanation
The intensity of influence of T_C	$r_i + d_j$	The greater the value $r_i + d_j$ for a criterion, the more interaction that criterion has with other criteria of the model.
The direction of influence of T_C	$r_i - d_j$	$r_i - d_j$>0, the relevant criterion is influences on the other, and if $r_i - d_j$ <0 the relevant criterion is influenced by the others
The intensity of influence of T_D	$\widetilde{R}_i + \widetilde{D}_j$	The greater the value of $\widetilde{R}_i + \widetilde{D}_j$ for a criterion, the more interaction that criterion has with other criteria of the model.
The direction of influence of T_D	$\widetilde{R}_i - \widetilde{D}_j$	If $\widetilde{R}_i - \widetilde{D}_j$>0, the relevant criterion influences the others, and if $\widetilde{R}_i - \widetilde{D}_j < 0$ the relevant criterion is influenced by the others.

Step 6. Drawing network relationship maps. In the next step, we will draw the Network Relations Map (NRM), a diagram with R+D on its horizontal axis and R-D on its vertical axis related to each criterion or dimension. To draw the NRM, we must first calculate the threshold value to ignore the minor relations and show the more important ones on the map. Note that only the relations that are valued in the T_C and T_D matrix is greater than the threshold value shown in the NRM. It is enough to calculate the relations threshold value, which is calculated using the opinion of the desired experts or the average values, for each T_C^{ij} (In the T_C matrix) as well as the average values of the T_D matrix (For drawing the dimensional relations map). For this purpose, the total relationship matrix of the dimensions and criteria is de-fuzzified using *Formula (4),* and after specifying the threshold values, all the smaller values are set to zero, and the causal relations will not be considered, and we show only the relationship that has values in the T_C and T_D matrix is greater than the threshold value in the network relationship map.

Step 7. Calculate the normalized total relationship matrix of dimensions (T_D^{α}). According to *Formula (13)*, at first, the T_D matrix was normalized; in this way, each row of this matrix was calculated, and then we divided each of the elements of each row by the sum of the components of the same row, and at the end, we changed the position of the rows and columns.

$$\widetilde{T}_D = \begin{bmatrix} t_{11}^{D_{11}} & \dots & t_{1j}^{D_{1j}} & \dots & t_{1m}^{D_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}} & \dots & t_{ij}^{D_{ij}} & \dots & t_{im}^{D_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{D_{m1}} & \dots & t_{mj}^{D_{mj}} & \dots & t_{mm}^{D_{mm}} \end{bmatrix} \begin{matrix} \longrightarrow \quad d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}}, \\ \\ \longrightarrow \quad d_2 = \sum_{j=1}^{m} t_{ij}^{D_{ij}}, \\ \\ \longrightarrow \quad d_3 = \sum_{j=1}^{m} t_{mj}^{D_{mj}}, \end{matrix} \quad i = 1, \dots, m. \tag{9}$$

$$\widetilde{T}_D^{\alpha} = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & \dots & t_{1j}^{D_{1j}}/d_1 & \dots & t_{1m}^{D_{1m}}/d_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}}/d_2 & \dots & t_{ij}^{D_{ij}}/d_2 & \dots & t_{im}^{D_{im}}/d_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{D_{m1}}/d_3 & \dots & t_{mj}^{D_{mj}}/d_3 & \dots & t_{mm}^{D_{mm}}/d_3 \end{bmatrix} = \begin{bmatrix} t_{11}^{\alpha_{11}} & \dots & t_{1j}^{\alpha_{1j}} & \dots & t_{1m}^{\alpha_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{\alpha_{i1}} & \dots & t_{ij}^{\alpha_{ij}} & \dots & t_{im}^{\alpha_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{\alpha_{m1}} & \dots & t_{mj}^{\alpha_{mj}} & \dots & t_{mm}^{\alpha_{mm}} \end{bmatrix}. \tag{10}$$

Step 8. Calculate the Normalized total relationship matrix of the criteria (T_C^α) and calculation of the unweighted supermatrix (W).

In this step, the T_C matrix is normalized using relations, and, in this way, the sum of each row of T_C^{ij} is calculated according to the relevant dimension. And then in each T_C^{ij}, each element is divided into the sum of the components of its corresponding line. For this purpose, we perform the desired operation for T_C^{11} for example, and do the same for others. Finally, by replacing the rows and columns of this matrix, the unweighted matrix (W) is obtained.

$$\begin{array}{c} \quad D_1 \quad \cdots \quad D_2 \quad \cdots \quad D_n, \\ C_{11} \cdots C_{1m_1} \; C_{j1} \cdots C_{jm_j} \; C_{n1} \cdots C_{nm_n}. \end{array}$$

$$\tilde{T}_C = \begin{array}{c} D_1 \; C_{11} \\ \vdots \\ \vdots \; C_{1m_1} \\ C_{j1} \\ D_2 \; \vdots \\ C_{jm_j} \\ \vdots \; C_{n1} \\ \vdots \\ D_n C_{nm_n} \end{array} \begin{bmatrix} t_{11}^{D_{11}} & \cdots & t_{1j}^{D_{1j}} & \cdots & t_{1m}^{D_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}} & \cdots & t_{ij}^{D_{ij}} & \cdots & t_{im}^{D_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{m1}^{D_{m1}} & \cdots & t_{mj}^{D_{mj}} & \cdots & t_{mm}^{D_{mm}} \end{bmatrix} \tag{11}$$

$$d_{ci}^{11} = \sum_{j=1}^{m} t_{c_{ij}}^{11}, \qquad i = 1, 2, \ldots, m. \tag{12}$$

$$\tilde{T}_C^{\alpha 11} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \cdots & t_{c1j}^{11}/d_{c1}^{11} & \cdots & t_{c1m1}^{11}/d_{c1}^{11} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{ci1}^{11}/d_{ci}^{11} & \cdots & t_{cij}^{11}/d_{ci}^{11} & \cdots & t_{cim1}^{11}/d_{ci}^{11} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{cm11}^{11}/d_{cm1}^{11} & \cdots & t_{cm1j}^{11}/d_{cm1}^{11} & \cdots & t_{cm1m1}^{11}/d_{cm1}^{11} \end{bmatrix}, \tag{13}$$

$$= \begin{bmatrix} t_{c11}^{\alpha_{11}} & \cdots & t_{c1j}^{\alpha_{1j}} & \cdots & t_{c1m}^{\alpha_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{ci1}^{\alpha_{i1}} & \cdots & t_{cij}^{\alpha_{ij}} & \cdots & t_{cim}^{\alpha_{im}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{cm1}^{\alpha_{m1}} & \cdots & t_{cmj}^{\alpha_{mj}} & \cdots & t_{cmm}^{\alpha_{mm}} \end{bmatrix}.$$

Step 9. Calculate the weighted supermatrix (W^α). In this step, the $\tilde{T}_D^\alpha$ matrix is multiplied by the supermatrix W in this way, we multiply each $t_D^{\alpha ij}$ by W_{ij} to obtain the weighted supermatrix W^α.

Step 10. Limiting and convergence of the weighted supermatrix. Based on *Eq. (18)*, the supermatrix is raised to the power of consecutive odd numbers so that all the numbers in each row of the matrix converge.

$$\lim_{Z\to\infty} (W^{\alpha l})^Z, \lim_{Z\to\infty} (W^{\alpha m})^Z, \lim_{Z\to\infty} (W^{\alpha n})^Z \;. \tag{13}$$

4 | Implementation and Analysis

After summarizing the experts' opinions, the definite numbers of each of the completed questionnaires were converted into their fuzzy equivalents using *Table 1*. Then, the average of these numbers was calculated to form the direct influence matrix. Then, to measure the reliability of the DANP questionnaire, *Eq. (14)* was used on the di-fuzzified D matrix, and the confidence level was calculated to be around 4.5%, which is lower than 5%, indicating the reliability of the results.

$$\frac{1}{n(n-1)}\sum_{i=1}^{n}\sum_{j=1}^{n}\left(\frac{t_{ij}^{p} - t_{ij}^{p-1}}{t_{ij}^{p}}\right). \tag{14}$$

Next, the third component of the fuzzy numbers of each criterion (In the row) was added together in matrix D, and the largest number in this set is 13.06, which is the parameter r. Then, matrix D's components were divided by this number for normalization, and matrix H was obtained. Then, T_C and T_D matrices were calculated. The following dimensions' intensity and direction of influence are shown in *Table 3,* and the criteria in *Table 4*, according to which dimensions A and C are effective, and dimension B is not effective

Table 3. The intensity and direction of the impact of dimensions.

Dimensions	R	D	R+D	R-D	Def (R+D)	Def (R-D)	Type
A	(0.09,0.24,1.31)	(0.1,0.28,1.37)	(0.19,0.52,2.68)	(-0.01,-0.04,-0.06)	0.98	-0.04	Influenced
B	(0.11,0.3,1.38)	(0.06,0.19,1.13)	(0.17,0.49,2.51)	(0.05,0.11,0.25)	0.92	0.13	Influences
C	(0.09,0.25,1.29)	(0.13,0.32,1.48)	(0.22,0.57,2.77)	(-0.04,-0.07,-0.19)	1.03	-0.09	Influenced

Table 4. The intensity and direction of the impact of the criteria.

Criteria	R	D	R+D	R-D	Def (R+D)	Def (R-D)	Type
A1	(0.2,0.48,2.84)	(0.23,0.59,2.95)	(0.43,1.07,5.79)	(-0.03,-0.11,-0.11)	2.09	-0.09	Influenced
A2	(0.18,0.46,2.63)	(0.27,0.63,2.95)	(0.45,1.09,5.58)	(-0.09,-0.17,-0.32)	2.0525	- 0.1875	Influenced
A3	(0.32,0.71,3.44)	(0.29,0.59,3.36)	(0.61,1.3,6.8)	(0.03,0.12,0.08)	2.5025	0.0875	Influences
A4	(0.24,0.56,2.9)	(0.26,0.61,2.96)	(0.5,1.17,5.86)	(-0.02,-0.05,-0.06)	2.175	-0.045	Influenced
A5	(0.27,0.65,3.31)	(0.26,0.62,3.19)	(0.53,1.27,6.5)	(0.01,0.03,0.12)	2.3925	0.0475	Influences
A6	(0.29,0.67,3.2)	(0.26,0.61,3.12)	(0.55,1.28,6.32)	(0.03,0.06,0.08)	2.3575	0.0575	Influences
A7	(0.25,0.64,3.14)	(0.18,0.52,2.92)	(0.43,1.16,6.06)	(0.07,0.12,0.22)	2.2025	0.1325	Influences
B1	(0.28,0.65,2.95)	(0.25,0.62,2.81)	(0.53,1.27,5.76)	(0.03,0.03,0.14)	2.2075	0.0575	Influences
B2	(0.26,0.62,2.77)	(0.23,0.59,2.8)	(0.49,1.21,5.57)	(0.03,0.03,-0.03)	2.12	0.015	Influences
B3	(0.16,0.51,2.57)	(0.22,0.59,2.71)	(0.38,1.1,5.28)	(-0.06,-0.08,-0.14)	1.965	-0.09	Influenced
B4	(0.1,0.42,2.4)	(0.28,0.69,3.12)	(0.38,1.11,5.52)	(-0.18,-0.27,-0.72)	2.03	-0.36	Influenced
B5	(0.25,0.62,2.83)	(0.2,0.54,2.7)	(0.45,1.16,5.53)	(0.05,0.08,0.13)	2.075	0.085	Influences
B6	(0.16,0.44,2.38)	(0.02,0.25,1.76)	(0.18,0.69,4.14)	(0.14,0.19,0.62)	1.425	0.285	Influences
B7	(0.2,0.59,2.83)	(0.21,0.59,2.8)	(0.41,1.18,5.63)	(-0.01,0.0,0.03)	2.1	0.005	Influences
C1	(0.16,0.5,2.49)	(0.11,0.36,1.93)	(0.27,0.86,4.42)	(0.05,0.14,0.56)	1.6025	0.2225	Influences
C2	(0.19,0.5,2.28)	(0.18,0.5,2.51)	(0.37,1.0,4.79)	(0.01,0.0,-0.23)	1.79	-0.055	Influenced
C3	(0.18,0.48,2.36)	(0.21,0.53,2.49)	(0.39,1.01,4.85)	(-0.03,-0.05,-0.13)	1.815	-0.065	Influenced
C4	(0.17,0.45,2.37)	(0.2,0.53,2.52)	(0.37,0.98,4.89)	(-0.03,-0.08,-0.15)	1.805	-0.085	Influenced
C5	(0.21,0.51,2.42)	(0.22,0.52,2.47)	(0.43,1.03,4.89)	(-0.01,-0.01,-0.05)	1.845	-0.02	Influenced

In the above table, the influenced and influence criteria are clear. Next, to draw network relation maps (NRM), T_C and T_D matrices were defuzzified, and the threshold value was calculated for each .Based on the calculations performed, the threshold value obtained for the T_D matrix was 0.1625. In this case, effects lower than this value from any dimension on another dimension will not be considered. And based on the calculations performed, the threshold values for each dimension were determined as follows: for dimension A, the threshold value was 0.1607; for dimension B, it was 0.1423; and finally, for dimension C, it was 0.1774. Any values in each category that are below these thresholds will not be considered.

Based on the intensity and direction information, network relations were drawn for the criteria and dimensions, which are shown in *Figs. 3-6*.

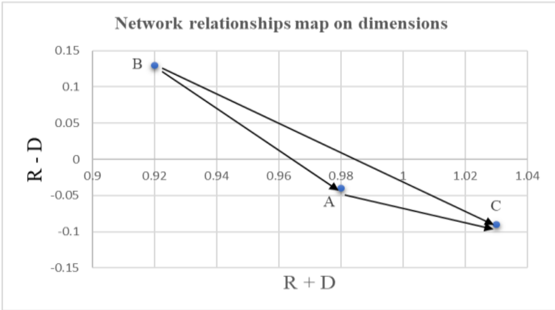

Fig. 3. Network relationships map on dimensions.

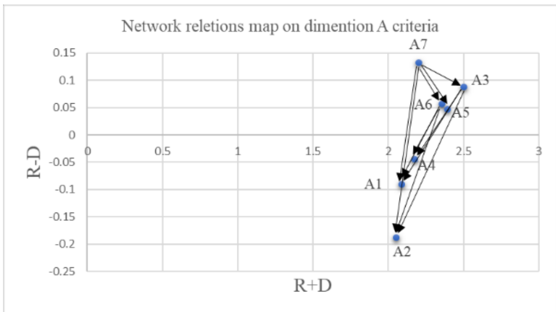

Fig. 4. Network relationships map on dimension A criteria.

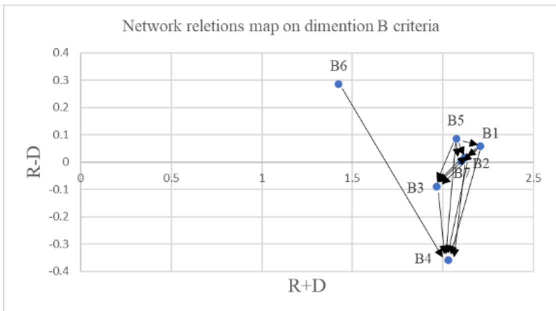

Fig. 5 network relationships map on dimension B criteria.

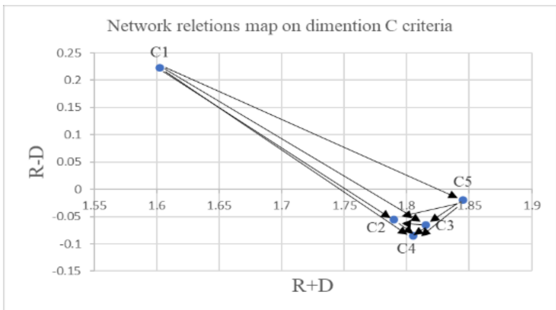

Fig. 6. Network relationships map on dimension C criteria.

In the following, according to the relations expressed in the previous sections, the T_C matrix is normalized, and the components of the fuzzy numbers of the unweighted supermatrix W are calculated. In the following, the supermatrix W was limited by exponentiation, which is the third power of the acceptable convergence matrix obtained.

4.1 | The Importance of Risks

After summarizing the opinions of the experts regarding the likelihood of occurrence and the severity of the effect of each risk that was obtained using the first questionnaire, the average of these numbers was calculated for each of them. In the following, all three criteria of the likelihood of occurrence, the severity of occurrence, and also the number obtained from the fuzzy DANP method for each risk are multiplied together. The final ranking of risks is shown in Table 5 in percentage from ascending to descending (It should be noted that, to simplify the issue, the likelihood of occurrence and the impact of risks are considered without mutual influence on each other).

Table 5. The final importance of risks.

Symbol	Risk Name	Importance
C2	Types of delays in the project	1.275
C4	Management of project changes and paying attention to them	1.136
C3	Trust between the team and the parties involved in the project	1.119
A3	Senior management's commitment to the project	0.984
C5	Effective relationships in the team and between project parties	0.901
C1	Entrance and exit of competitors from the market	0.873
B4	Stability of project financial issues	0.868
A1	The ability of the responsible person to risk tracking	0.861
A2	The team's ability to adapt to the agile approach	0.661
B1	Economic stability of the country	0.640
A5	Systematic, long-term, and strategic view	0.621
A6	Standardization of processes and clarity of goals and processes	0.603
A7	Size and culture of the organization	0.501
B2	Political and security stability of the country	0.473
A4	Contract and documents required for the project	0.465
B3	Legal changes that affect the project	0.460
B5	Change of people who influence the project in the country	0.430
B7	Workforce and infrastructure of the country	0.420
B6	Natural disasters	0.182

4.2 | Analysis of the results

In this section, the identified risks were categorized into three categories: "organizational risks", "environmental risks", and "joint organizational and environmental risks". Using the tools available in the DANP technique, the results of the questionnaires were evaluated for reliability, and the gap percentage of experts' opinions was calculated as 4.5%, which was lower than the allowed value of 5%. The results showed that they are reliable. The results of the DANP technique revealed, as anticipated, that "organizational risks" and "joint organizational and environmental risks" were identified as influential. In this context, the risks associated with "natural disasters" and "market entry and exit of competitors" were found to have the most significant impact on other risks. Additionally, the risks concerning "the stability of the project's financial issues" and "the team's ability to adapt to an agile approach" exhibited the highest degree of influence over other risk factors.

To rank the risks, the numerical values derived from the DANP method were multiplied by the corresponding likelihood of occurrence and the severity of their impact. In this ranking, "types of delays in the project" emerged as the highest priority risk, followed by the risks associated with "managing project changes" and "trust among the team and stakeholders," which ranked next, respectively. All three risks are categorized as "shared risks between the organization and the environment." Overall, the ranking revealed that "shared organizational and environmental risks" ranked highest, followed by "organizational risks," and lastly, "environmental risks". The analysis of the questionnaire results indicates that "joint organizational and environmental" risks are the most critical in projects, necessitating closer monitoring than other types of risks to prevent project failure.

5 | Conclusion

After applying the fuzzy DANP method to the data collected from the questionnaires, it was found that Dimension B is in a positive influence direction, while Dimensions A and C are in a negative influence direction. Furthermore, it was noted that, in terms of the interplay of risks, the risk of "natural disasters" and the risk of "entrance and exit of competitors from the market" had the most significant impact. Additionally, "stability of project financial issues" and "the team's ability to adapt to the agile approach" emerged as some of the most influential risks. The final ranking of risks was determined by multiplying three factors: the likelihood of occurrence, the severity of impact, and the values derived from the fuzzy DANP method. This analysis revealed that the risks associated with "types of delays in the project," "management of project changes and attention to them," and "trust between the team and stakeholders" are categorized under the dimension of "common organizational and environmental risks." These risks are significantly more important than the others identified in the assessment.

The following recommendations are proposed for future research:

I. Since the risks assessed in this study encompassed all aspects of risk management for agile projects, many of which may also apply to traditional projects, it is advisable to reevaluate the risk ranking by focusing exclusively on the risks that are specific to agile projects.

II. To implement the agile risk management approach, it is recommended to conduct a case study in which a project is executed. In the initial phase, risks affecting agile projects can be identified more accurately and realistically. In the subsequent phase, the significance of each risk can be assessed realistically, and the risk ranking can be adjusted if necessary.

III. Additionally, since selecting the appropriate methods and techniques for managing risk is a crucial step in risk management, future research should emphasize evaluating the effectiveness of these approaches and their impact on the risks and outcomes of agile projects.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

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