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Assessing Start-Up Project Risks with Statistical Techniques: A Multi-Objective Approach Using SWARA and Fuzzy WASPAS

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Abstract

Start-up projects are increasingly gaining attention from investors and entrepreneurs due to changing paradigms, making their evaluation essential. But problem is that start-ups like any other firms have some risks that they are not familiar with. On the other hand, there is less research in literature which explore and assess start up project risks that can be considered as a gap. This research addresses a gap in the literature by comprehensively identifying, evaluating, and managing risks associated with start-up projects. Utilizing FMEA, fuzzy MCDM, and a mathematical model, the study aims to rank the risks of start-up projects and determine optimal strategies to mitigate them. Fuzzy MCDM technique in weighting part was Swara that was used for determination of measures weight and in ranking part was WASPAS that was used for ranking alternatives. The projects examined include Snapp, Tapsi, DigiKala, Aparat, CafeBazzar, and Alopeyk in Iran. The results reveal that time is the most significant risk factor, with a value of 0.53, followed by cost at 0.30 and quality at 0.17. Furthermore, the most critical risks identified include resource shortages and supply challenges, closely followed by team size, time pressures, and the business plan, with uncertainty ranking prominently as well. The final analysis provides optimal strategies focused on minimizing time and cost, emphasizing their optimization in risk response. This research can help managers to decide about project based on their risks and also start up business population can get information about probable risks of their project before and after running them.

Keywords: Risk management, Startup projects, SWARA, WASPAS, Fuzzy theory.

Paper Type: Original Research

1. Introduction

While project risk management is a well-established field, the unique ecosystem of start-up projects presents distinct challenges that are not adequately addressed by conventional models. The risks associated with projects encompass a range of uncertain and unpredictable events that can disrupt processes, lead to delays, increase costs, and pose significant challenges. Consequently, contractors and project managers are compelled to minimize these risks, which are intrinsic to all economic activities, including project management (He, Wang et al. 2024). It's important to recognize that risks can vary considerably based on different conditions and contexts; thus, a universal definition of risk applicable to all projects does not exist. For example, the risk landscape for software projects differs substantially from that of construction projects (Gichohi, Iravo et al. 2024). Project managers must effectively assess and manage their projects to prevent risks from escalating into crises that disrupt workflows (Bepari, Narkhede et al. 2024) . In the business sector, startup projects have emerged as a significant concept, coinciding with the rise of startups themselves. A startup project is defined as any initiative undertaken by a startup company (Karaarslan and Soylu 2023). While these nascent enterprises are often inexperienced, they possess immense potential for growth and job creation. However, like all economic activities, startup projects carry inherent risks that must be identified, evaluated, and managed from the outset. Start-ups operate under extreme uncertainty, with fragile financial structures, rapid pivots, and a high propensity for failure; statistics indicate approximately 90% fail within their initial years, often due to a lack of market need, financial challenges, and timing issues. Among these failures, 42 percent are attributed to a lack of market need, 14 percent to insufficient customer engagement, and 13 percent to timing issues for product launches. Additionally, research shows that between 70 to 90 percent of startups encounter difficulties within 20 months of receiving funding, with 38 percent failing due to financial challenges and 35 percent due to weak market demand. These figures underscore the high failure rates and risks associated with startup projects, highlighting their susceptibility to bankruptcy in a short timeframe. (Fauzi,

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Ghazali et al. 2022). Addressing the risks inherent in startup projects requires a comprehensive three-step process: identification, evaluation, and management. Each phase of a startup project—investment, execution, and delivery—carries specific risks that need to be addressed. Therefore, it is essential to identify these risks while simultaneously advancing the startup initiatives. One notable gap in the current literature is the lack of comprehensive studies focusing on the identification, evaluation, and management of risks specific to startup projects. Although some research highlights various risks and theoretical frameworks exist for risk evaluation and management, targeted studies on startup projects are limited. Given the increasing significance and effectiveness of startups in the business landscape, this area merits further exploration. Because of literature gap in this field and also not consideration of startup project risks in literature and importance of startup roles in future of economy and employment, the primary objective of this research is to identify, evaluate, and manage the risks associated with startup projects using a combination of multi-criteria decision-making (MCDM) techniques, statistical methods, and strategic planning under uncertainty. The study begins with a literature review and insights from experts to identify risks, which are subsequently validated through statistical analysis and quantified using Failure Mode and Effects Analysis (FMEA). Risk measures are then weighted using Fuzzy SWARA, and risks are ranked through Fuzzy WASPAS. The research culminates in optimizing risk management strategies, ensuring the best decisions are made based on the identified risks. We employ a unique combination of techniques: statistical tests (e.g., t-test) for risk validation, Failure Mode and Effects Analysis (FMEA) for quantification, the fuzzy SWARA method for weighting risk measures, and the fuzzy WASPAS technique for prioritization. This synergy of methods enhances the robustness and credibility of the risk assessment under uncertainty. The primary objective of this research is to identify, evaluate, and manage risks associated with start-up projects using this hybrid approach. Ultimately, this study aims to provide start-up founders and project managers with a practical, data-driven toolset to navigate inherent uncertainties, thereby increasing their resilience and chances of success. The article is organized as follows: Section 2 provides the literature review; Section 3 details the methodology and methods employed; Section 4 discusses the implementation of the model; and Section 5 concludes the study.

2. Literature Review

This section provides a review of research studies pertinent to the current investigation, specifically focusing on works from the last four years that address the evaluation and management of project risks. This review aims to highlight the research gap that our study seeks to fill. Startup firms are instrumental in driving national economic growth, contributing to increased competition, innovation, and job creation. A startup is a temporary organization focused on developing a profitable, scalable, and repeatable business model. In contrast to smaller divisions of larger corporations, startups tend to target unmet market needs, creating opportunities for both profitability and growth. The activities undertaken by startups, referred to as startup projects, exhibit project-like characteristics and involve specific scheduling and budgeting, often manifested as new startup companies. Startups that exhibit substantial growth potential also face a range of uncertainties due to their fragile financial and organizational structures. This inherent vulnerability subjects them to various challenges and risks. Therefore, it becomes evident that startups encounter distinct risks during project execution that require special attention. In this section, we will explore some of these unique risks in greater detail.

Table 1. start-up project's risks

No	Risk	Reference	No	Risk	Reference
1	Resource shortage	Teberga, Oliva et al. (2018)	11	Single product	Karaarslan and Soylu (2023)
2	Innovation	Teberga, Oliva et al. (2018)	12	Low experience team	Harrison and Mason (2017)
3	Uncertainty	Giardino, Unterkalmsteiner et al. (2014)	13	Business plan	Fauzi, Ghazali et al. (2022)
4	Time pressure	Polishchuk, Kelemen et al. (2019)	14	Primary investment	Giardino, Unterkalmsteiner et al. (2014)
5	Quick changes	Fauzi, Ghazali et al. (2022)	15	Market	Fauzi, Ghazali et al. (2022)
6	Dependency to third-party	Polishchuk, Kelemen et al. (2019)	16	Technical experience	Harrison and Mason (2017)
7	Small teams	Polishchuk, Kelemen et al. (2019)	17	Process inefficiency	Festel, Wuermseher et al. (2013)
8	Investment in research and development	Karaarslan and Soylu (2023)	18	financing	Harrison and Mason (2017)
9	Social network	Karaarslan and Soylu (2023)	19	Associations and marketing strategies	Festel, Wuermseher et al. (2013)
10	Gain and loss	Karaarslan and Soylu (2023)			

Qian and Lin (2016) investigate safety risk management in underground engineering within China, examining strategies, challenges, and recent advancements in the field. Dandage, Mantha et al. (2018) delve into the interactions among barriers in project risk management. Andrić, Wang et al. (2019) identify key risks in railway projects utilizing sensitivity and fuzzy analysis, with a specific focus on road and belt projects. Nunes and Abreu (2020)consider open innovation project risks through the lens of social network analysis. Marle (2020) contributes to project risk management by applying complex systems and agile project management techniques. Nunes, Abreu et al. (2021) develop a model for managing risks in collaborative projects aimed at fostering knowledge creation and promoting sustainable business practices. Antoniou (2021) presents several models dedicated to evaluating delay risks in road projects. Alvand, Mirhosseini et al. (2023) identify and assess risks in construction projects using the SWARA, FMEA, and WASPAS methodologies within a fuzzy context, specifically targeting construction projects in Iran. Bepari, Narkhede et al. (2024) perform a comparative study on project risk management focusing on failure structures. Erlita, Amin et al. (2023) explore multi-step project risk management for construction projects in the food manufacturing industry. Senova, Tobisova et al. (2023) propose innovative approaches for project risk evaluation leveraging Monte Carlo methodologies. Nikolaenko and Sidorov (2023) analyze risks associated with information technology projects. Alawneh, Jannoud et al. (2024) introduce a novel method for evaluating project risk in sustainable construction projects within developing countries. He, Wang et al. (2024) assess advancements and systematic risk analysis concerning investment safety in water transfer projects and operational failures. Nge'tich and Munene (2024) investigate the impacts of project risk management on road projects in Kenya, while Gichohi, Iravo et al. (2024) examine its influence on the performance of road construction projects in the same region. Lastly, Khalilzadeh, Banihashemi et al. (2024) propose a hybrid stepwise approach that integrates multi-criteria methodologies with multi-objective optimization models for effective project risk management. Upon reviewing the literature, we observe that some studies, such as those conducted by Andrić, Wang et al. (2019) and Alvand, Mirhosseini et al. (2023), primarily concentrate on risk identification. In contrast, other research efforts, including those by Dandage, Mantha et al. (2018), Antoniou (2021), and Senova, Tobisova et al. (2023), focus on risk evaluation. A considerable number of studies address risk management, with notable contributions from Nunes, Abreu et al. (2021), and Marle (2020). However, there is a scarcity of research that concurrently examines all three dimensions: identification, evaluation, and management. Moreover, Alvand, Mirhosseini et al. (2023) and Alawneh, Jannoud et al. (2024) integrate uncertainty into their risk evaluation processes. Methodologically, the studies by Erlita, Amin et al. (2023) and Alvand, Mirhosseini et al. (2023) employ multi-criteria decision-making (MCDM) techniques. Heydarpour et al(2023) provide a DEA and AHP hybrid model to evaluate contractors performance. Rasouli et al(2023) evaluate risk factors in solar energy investment. They have a strategic approach for iran market. Ayough et al(2022) provide a new interactive method based on multi criteria preference degree functions for solar power plant site selection. Overall, the literature review reveals a significant gap in addressing the evaluation and management of risks specifically associated with startup projects. In particular, there is a lack of research utilizing hybrid techniques that combine statistical analysis, MCDM, and multi-objective mathematical models for effective project risk management. Given the growing importance of startup projects in the contemporary business landscape, it is essential to focus more intently on the risks they face. To address this identified gap, this research introduces several key innovations:

- Defining a hybrid approach that integrates risk identification, evaluation, and management
- Focusing on the specific risks associated with startup projects
- Considering the uncertainty in the risk assessment process
- Optimizing the risk response strategies
- Developing a model along with proposed solution

Table 2. Related literature on this issue

References	Objective	Risk identification	Risk evaluation	Risk management	Startup projects	Multi criteria decision making	uncertainty	Multi-objective programming
Qian and Lin (2016)	Consideration of safety risk management in underground engineering in China and its strategies, challenges and advancement			✓				
Dandage, Mantha et al. (2018)	Analysis of interactions among barriers in project risk management		✓	✓				
Andrić, Wang et al. (2019)	Identification of main risks in railway project based on sensitivity and fuzzy analysis	✓						
Nunes, Abreu et al. (2021)	Open innovation project risk management based on social network analysis perspective			✓				
Marle (2020)	Project risk management based on complex systems theories and agile project management			✓				
Antoniou (2021)	Delay risk evaluation models for road projects		✓					
Nunes, Abreu et al. (2021)	A model for risk management of collaboration project for knowledge creation and advancement of sustainable business			✓				
Alvand, Mirhosseini et al. (2023)	Identification and evaluation of risk in construction projects using SWARA FMEA and fuzzy WASPAS	✓	✓			✓	✓	
Bepari, Narkhede et al. (2024)	Comparative study of project risk management with risk failure structure			✓				
Erlita, Amin et al. (2023)	Multi step project risk management on construction of food manufacturing factory		✓	✓		✓		
Senova, Tobisova et al. (2023)	New approaches in order to evaluate project risk using Mont-Carlo method		✓					
Alawneh, Jannoud et al. (2024)	New method for project risk evaluation in sustainable construction project in developing country		✓			✓	✓	
He, Wang et al. (2024)	Advancement and investment safety risk analysis in water transfer and casual failure importance		✓					
Nge'tich and Munene (2024)	Exploration of project risk management impact on road project of Kenia			✓				
Gichohi, Iravo et al. (2024)	Project risk management on road construction projects performance			✓				
Khalilzadeh, Banihashemi et al. (2024)	A stepwise hybrid approach based on multi criteria decision making and multi objective optimization model for project risk management			✓				✓
Current research	Identification, evaluation and management of start-up projects risks using statistical techniques, SWARA, fuzzy WASPAS and multi objective mathematical model	✓	✓	✓	✓	✓	✓	✓

3. Research methodology

This study employs a hybrid methodology that integrates statistical methods, multi-criteria decision-making (MCDM), and fuzzy multi-objective mathematical models for the evaluation and management of project risks. The research process is illustrated in Figure 1. Initially, project risks associated with startup initiatives are identified and then validated using a t-test. Following this validation, risks are quantified through the application of Failure Mode and Effects Analysis (FMEA). Subsequently, risk measures are weighted using the SWARA method, and prioritization is executed via the fuzzy WASPAS technique. The values obtained from fuzzy WASPAS for each identified risk are incorporated into a multi-objective mathematical model as a key objective. The statistical population for this study consists of experts in startup projects based in Tehran. Given the purpose-driven nature of the sample selection, a participant group of 10 to 20 individuals is considered adequate, with 15 experts chosen for this research. A snowball sampling method is employed, where the initial participant is asked to recommend another potential participant, continuing until theoretical saturation is reached. Data collection is conducted through a combination of surveys and library research. The library research helps identify startup project risks, and expert interviews further enrich the findings. To determine appropriate risk response strategies, surveys concerning risk measures and responses are utilized. Quantitative assessments of risks involve surveys dedicated to measuring weights and prioritization. Several analytical techniques are applied in this study, including:

- FMEA for risk quantification
- SWARA for weighting risk measures
- Fuzzy WASPAS for risk prioritization
- Multi-objective mathematical modeling for optimizing risk response strategies

FMEA serves as the key technique employed following the identification of risks, aiming to quantify these risks using three critical indicators: occurrence probability, severity, and detection probability. By combining these indicators, we generate the Risk Priority Number (RPN), which reflects the significance of each risk and facilitates the quantification of risks identified in the earlier stage. To weigh risk measures, the fuzzy SWARA technique is applied. This technique, similar to AHP, ANP, BWM, and Shannon entropy, allows for the effective weighting of measures. Given the inherent uncertainty of this method, experts provide weight assessments across three levels: probable, lower, and upper. These established weights are then utilized in the next step of risk prioritization.

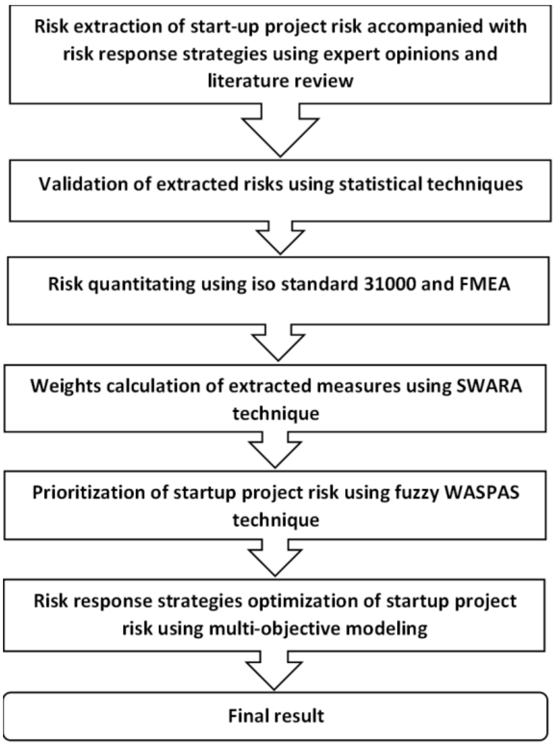

Figure 1. The proposed methodology

For prioritizing alternatives, the WASPAS technique is employed, which shares similarities with MURA, TOPSIS, Multi MURA, and COPRAS. When used in conjunction with the weighting technique, WASPAS effectively prioritizes alternatives. In this study, it is specifically used to prioritize risks associated with startup projects, with risk values serving as inputs for the subsequent mathematical model. Notably, the WASPAS technique follows a fuzzy model, allowing experts to input uncertain values into the decision matrix in three forms: probable, optimistic, and pessimistic.

3.1. Multi-objective mathematical model

Multi-objective mathematical model at first objective aim to minimize risk response strategy risk while second objective aim to minimize risk response time and third objective seek to minimize total risk of project based on results from fuzzy WASPAS, mathematical programming model is as following:

Sets

i	Types of risks
j	Types of strategies

Parameters

P_i	Risk i occurrence probability
W_{ij}	Strategy i execution cost against risk i
L_{ij}	Spent time for implementation of strategy j against risk i
WS_{ij}	Risk i score based on fuzzy WASPAS method
E_{ij}	Impact of strategy on cost due to risk i occurrence level of cost reduction after implementation of strategy j for overcoming on risk I occurrence
S_{ij}	Impact or strategy on time delay due to risk I occurrence number of improved days after implementation of strategy j for overcoming on risk occurrence i
C_i	Cost due to risk i occurrence
T_i	Time delays due to risk i occurrence
D	Final delay in project implementation

Decision variable

X_{ij}	1 if strategy j is assigned to risk i; 0, otherwise

Using indexes, parameters and decision variable, the mathematical model is written as follows:

$$\min Z1 = \sum_{i=1}^{I}\sum_{j=1}^{J} P_i W_{ij} X_{ij} \quad (1)$$

$$\min Z2 = \sum_{i=1}^{I}\sum_{j=1}^{J} P_i L_{ij} X_{ij} \quad (2)$$

$$\min z3 = \sum_{i}^{I}\sum_{j}^{J} WS_i X_{ij} \quad (3)$$

s.t.

$$\sum_{j=1}^{J} W_{ij} X_{ij} \leq C_i \qquad \forall i \quad (4)$$

$$\sum_{j=1}^{J} L_{ij} X_{ij} \leq T_i \qquad \forall i \quad (5)$$

$$\sum_{j=1}^{J} X_{ij} \geq 1 \qquad \forall i \tag{6}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} E_i X_{ij} \geq \sum_{i=1}^{I}\sum_{j=1}^{J} W_{ij} X_{ij} \tag{7}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} S_i X_{ij} \geq \sum_{i=1}^{I}\sum_{j=1}^{J} L_{ij} X_{ij} \tag{8}$$

$$\sum_{i=1}^{I} T_i - \sum_{i=1}^{I}\sum_{j=1}^{J} S_i X_{ij} \leq K \tag{9}$$

$$X_{ij} \qquad \forall i,j \tag{10}$$

The objectives of the mathematical model are defined as follows:
Objective (1): Minimize the implementation costs of risk response strategies.
Objective (2): Minimize the time duration required for the implementation of risk response strategies.
Objective (3): Assign strategies to risks that exhibit the lowest scores according to the fuzzy WASPAS method.
The constraints of the model are outlined as follows:
Constraint (4): Ensure that the selection of strategies prevents the implementation costs associated with each risk from exceeding the potential losses due to that risk, in accordance with established cost constraints.
Constraint (5): Ensure that the time required for the implementation of strategies for each risk does not exceed the delays caused by those risks.
Constraint (6): Mandate that at least one strategy must be selected from the available options for each identified risk.
Constraint (7): Ensure that the costs of the selected strategies align with the cost constraints, such that their impact on the overall project cost is greater than or equal to the implementation costs of those strategies.
Constraint (8): Ensure that the selected strategies comply with time constraints, such that their effect on project completion time is greater than or equal to the implementation times of those strategies.
Constraint (9): Ensure that the selection of strategies adheres to time constraints, such that the total delay caused by existing risks exceeds the maximum allowable delay impact on project completion.
Constraint (10): Specify the type of decision variable used in the model.
The mathematical model is detailed in the preceding section, and the subsequent section will present an analysis of the model based on the input data, along with the findings derived from this analysis.

3.2. Data collection

The raw data utilized for the analysis was gathered from a selection of expert sources within various startup companies. The following companies were included in the study:

- Snapp: A transportation startup that facilitates the transfer of people and cargo through a specialized mobile application in Iran.
- Tapsi: A transportation startup operating similarly to Snapp.
- Digikala: A prominent online retailer offering a wide range of products through its website.
- Alopeyk: A motorcycle-based startup dedicated to the delivery of various types of cargo.
- Apparat: A video platform that allows users to upload any authorized video content, functioning similarly to YouTube.
- Cafebazzar: A startup focused on supplying a diverse array of mobile applications.
- Divar: An advertising startup catering to various needs in Tehran and other cities across Iran.

The data encompasses inputs extracted from experts to validate relevant factors, which are subsequently used for the SWARA method, FMEA, and WASPAS analyses. The input data is based on numerical assessments gathered from active experts across the aforementioned companies.

4. Results

In this section, we present a comprehensive analysis of the findings derived from our research, following the established methodological steps outlined previously. The results elucidate the significant factors identified through expert insights and the subsequent applications of the SWARA method, FMEA, and WASPAS techniques. Initially, we applied the SWARA method to prioritize the critical factors influencing the performance and strategic decisions of the featured startups. By engaging with experts from each company, we were able to gather qualitative data that informed a weighted ranking of these factors. The findings indicate a clear consensus among experts regarding the top determinants of success in their respective sectors, with factors such as customer experience, technology integration, and market adaptability emerging as paramount. Following the SWARA method, we employed FMEA to assess the potential risks associated with each identified factor. This analysis provided a quantitative measure of risk priority numbers (RPNs), enabling us to pinpoint areas requiring immediate attention. The results revealed several high-risk factors within various startups, emphasizing the need for robust risk management strategies to mitigate potential adverse impacts. Finally, we utilized the WASPAS method to integrate the qualitative and quantitative data collected to facilitate a multi-criteria decision-making process. The results from this analysis demonstrated how the startups can optimize their operations and strategic initiatives by balancing various criteria, including cost, efficiency, and customer satisfaction. Overall, the findings underscore the importance of a systematic approach to analyzing complex data sets within startup environments. The synthesis of qualitative insights and quantitative assessments not only contributes to a deeper understanding of the operational landscape but also provides actionable recommendations for enhancing performance and mitigating risks.

4.1. Validation of extracted risks using statistical techniques

In the initial phase of our analysis, we utilized the t-test methodology to validate the associated risks concerning the various conditions and projects of the startups outlined in Table 3. This statistical approach allowed us to rigorously assess the significance of differences between groups, thereby facilitating a deeper understanding of the factors impacting startup performance.

Table 3. validation of extracted risks

Factors	T-statistic	Significant level	Average difference	95 % confidence	
				Lower	Upper
Resource shortage	10.783	.000	3.13333	2.5101	3.7566
Innovation	8.214	.000	2.80000	2.0689	3.5311
Uncertainty	7.536	.000	2.53333	1.8123	3.2544
Time pressure	7.519	.000	3.06667	2.1919	3.9414
Quick changes	6.546	.000	2.06667	1.3895	2.7438
Dependency to third party	7.643	.000	2.93333	2.1102	3.7565
Small teams	10.986	.000	3.33333	2.6826	3.9841
Being single product	7.483	.000	2.40000	1.7121	3.0879
Low experience team	8.526	.000	3.00000	2.2453	3.7547
Business plan	11.374	.000	2.06667	1.6770	2.4564
Primary investment	7.062	.000	3.26667	2.2746	4.2588
Market	6.866	.000	3.13333	2.1546	4.1121
Technical experience	6.517	.000	2.53333	1.6996	3.3671
Process inefficiency	6.141	.000	2.53333	1.6486	3.4181
Investment in research and development	9.740	.000	3.13333	2.4434	3.8233
Financing	8.047	.000	2.46667	1.8092	3.1241
Social network	9.379	.000	3.40000	2.6224	4.1776
Communication and strategies of marketing	10.058	.000	3.73333	2.9372	4.5294
Gain and loss	7.614	.000	2.80000	2.0113	3.5887

As we observe all of risks are significant in confidence level of 95 percent since significance for all risks are close to zero and less than 0.05 and therefore validation of all risks can be confirmed.

4.2. Quantitation of risk using iso 31000 standard and FMEA

In this section, we conducted risk quantification utilizing the Failure Mode and Effects Analysis (FMEA) methodology. The findings from this analysis are detailed in Table 4. By systematically identifying potential failure modes and their associated impacts, we were able to assess the relative risks inherent in the studied projects. This quantitative approach not only highlights critical areas of concern but also provides a framework for prioritizing risk mitigation efforts.

The results presented in Table 4 offer valuable insights into the risk landscape, enabling informed decision-making for future project developments.

Table 4. risk quantification using FMEA

NO	Risk	Occurrence probability	Occurrence intensity	Detection probability	RPN
1	Resource shortage	4	3	4	48
2	Innovation	7	5	1	35
3	uncertainty	7	2	2	28
4	Time pressure	7	10	2	140
5	Quick changes	10	6	8	480
6	Dependency to third party	6	7	10	420
7	Small teams	4	5	4	80
8	Being single product	9	10	2	180
9	Low experience team	8	1	7	56
10	Business plan	2	8	1	16
11	Primary investment	9	2	4	72
12	Market	6	5	7	210
13	Technical experience	3	3	10	90
14	Process inefficiency	3	9	1	27
15	Investment in research and development	9	8	2	144
16	Financing	5	3	6	90
17	Social network	2	5	5	50
18	Communication and strategies of market-ing	9	8	7	504
19	Gain and loss	7	8	1	56

The Risk Priority Number (RPN) values, which indicate the significance of each identified risk, have been derived from the data presented in the preceding table. The RPN is calculated by multiplying the probabilities of occurrence, severity of occurrence, and detection probability. This metric facilitates a clear understanding of the relative importance of each risk, serving as a basis for prioritizing risk management efforts.

4.3. Calculation of weights using SWARA technique

In this section, weighting measures for each identified risk were assessed using the SWARA method. Three critical measures related to startup project risks were established, grounded in key project management components. These measures—time, cost, and quality—are detailed in Table 5, which presents the calculated weighting results obtained through the SWARA method.

Table 5. weighting risk measure

Risk measure	Relative importance average	Kj	Primary weight	Normal weight
Time	1	1	1	0.532839
Cost	0.763646	1.763646	0.567007	0.302124
Quality	0.830645	1.830645	0.309731	0.165037
Total sum			1.876738	1.000000

The SWARA method reveals that the time measure holds the highest importance, followed by cost and quality. The weight assigned to each measure is calculated based on the normalized weights, which will serve as inputs for the fuzzy WASPAS method in the subsequent step.

4.4. Prioritization of start-up project risk using fuzzy WASPAS technique

The fuzzy decision matrix for the WASPAS method is presented in Table 6 and the fuzzy numbers, derived from the average inputs of the experts, are shown in the table 7. Utilizing this matrix, we can compute the fuzzy normal matrix for the WASPAS method, which is presented in Table 7. By calculating the normal fuzzy matrix, we can derive the weighted fuzzy normal matrix by multiplying the normal matrix by the measure weights. The resulting matrix is presented in Table 8. Finally, by calculation of values of P and Q (Table 9) and defuzzification we can calculate K value that indicate final ranking of each measure. The values are displayed in table 10.

Table 6. fuzzy decision matrix of WASPAS method

Factors	Time			Cost			Quality		
	0.533			0.302			0.165		
Resource shortage	0.7628	0.816	0.862	0.592	0.658	0.704	0.874	0.942	1
innovation	0.082	0.161	0.196	0.4064	0.457	0.499	0.646	0.675	0.741
uncertainty	0.601	0.641	0.709	0.575	0.650	0.676	0.657	0.718	0.797
Time pressure	0.974	1	1	0.611	0.682	0.753	0.1477	0.222	0.245
Quick changes	0.18	0.211	0.233	0.281	0.312	0.348	0.369	0.391	0.430
Dependency to third party	0.195	0.211	0.269	0.772	0.833	0.874	0.206	0.2702	0.361
Small teams	0.953	1	1	0.958	0.998	1	0.139	0.202	0.263
Being single product	0.092	0.105	0.126	0.0959	0.129	0.193	0.905	0.9549	1
Low experience team	0.229	0.316	0.367	0.709	0.763	0.801	0.410	0.478	0.536
Business plan	0.788	0.807	0.896	0.81	0.866	0.963	0.234	0.321	0.344
Primary investment	0.638	0.738	0.785	0.757	0.79	0.88	0.251	0.275	0.330
market	0.0921	0.144	0.229	0.193	0.253	0.319	0.634	0.659	0.738
Technical experience	0.173	0.200	0.291	0.543	0.573	0.663	0.28	0.320	0.331
Process inefficiency	0.595	0.637	0.699	0.100	0.127	0.183	0.191	0.212	0.282
Investment in research and development	0.102	0.134	0.171	0.230	0.241	0.252	0.717	0.757	0.835
Financing	0.984	1	1	0.998	1	1	0.232	0.242	0.3205
Social network	0.327	0.3890	0.448	0.482	0.569	0.646	0.904	0.931	1
Communication and strategies of marketing	0.444	0.537	0.561	0.872	0.9712	1	0.0681	0.105	0.126
Gain and loss	0.094	0.188	0.21	0.7665	0.7842	0.8581	0.752	0.831	0.9281

Table 7. Fuzzy normal matrix of WASPAS

Factor	time			Cost			Quality		
	0.533			0.302			0.165		
Resource shortage	0.775155	0.816575	0.862357	0.593729	0.657598	0.704717	0.965625	0.98651	1
innovation	0.084067	0.161634	0.196961	0.407277	0.457332	0.499566	0.714335	0.707448	0.741274
uncertainty	0.611567	0.641883	0.709569	0.576184	0.650476	0.676492	0.725756	0.752267	0.797913
Time pressure	0.990534	1	1	0.61274	0.682043	0.753526	0.163199	0.232673	0.24592
Quick changes	0.183233	0.211675	0.233987	0.282501	0.312002	0.348351	0.407724	0.410214	0.430304
Dependency to third party	0.198244	0.211853	0.269494	0.77438	0.83371	0.874876	0.227635	0.282985	0.36177
Small teams	0.968748	1	1	0.960222	0.998199	1	0.154047	0.211898	0.263172
Being single product	0.094311	0.105878	0.126969	0.096087	0.129041	0.193097	1	1	1
Low experience team	0.233685	0.316045	0.367786	0.710447	0.763294	0.801663	0.453074	0.500905	0.536053
Business plan	0.801245	0.807647	0.896574	0.819229	0.866523	0.963385	0.258728	0.336204	0.344663
Primary investment	0.64918	0.738778	0.785202	0.75931	0.791094	0.881781	0.277678	0.28873	0.330689
market	0.093657	0.144294	0.229469	0.193555	0.253795	0.319058	0.700884	0.69093	0.738221
Technical experience	0.176037	0.200837	0.291376	0.544515	0.5739	0.663756	0.316148	0.33584	0.331984
Process inefficiency	0.604669	0.637929	0.699363	0.100268	0.127049	0.183987	0.21113	0.22252	0.282498
Investment in research and development	0.104111	0.134708	0.17138	0.230787	0.241549	0.252117	0.79265	0.793264	0.835285
Financing	1	1	1	1	1	1	0.256266	0.253981	0.320505
Social network	0.332342	0.389029	0.448043	0.483511	0.569877	0.646086	0.998884	0.975342	1
Communication and strategies of marketing	0.451413	0.537055	0.56168	0.874183	0.971213	1	0.075265	0.110242	0.126866
Gain and loss	0.096085	0.188298	0.21371	0.768058	0.784264	0.858109	0.831032	0.871274	0.92861

Table 8. Weighted fuzzy normal matrix of WASPAS

Factors	Time			Cost			Quality		
	0.533			0.302			0.165		
Resource shortage	0.413158	0.435235	0.459636	0.179306	0.198595	0.212825	0.159328	0.162774	0.165
innovation	0.044808	0.086151	0.10498	0.122998	0.138114	0.150869	0.117865	0.116729	0.12231
uncertainty	0.325965	0.342124	0.3782	0.174008	0.196444	0.204301	0.11975	0.124124	0.131656
Time pressure	0.527955	0.533	0.533	0.185047	0.205977	0.227565	0.026928	0.038391	0.040577
Quick changes	0.097663	0.112823	0.124715	0.085315	0.094225	0.105202	0.067274	0.067685	0.071
Dependency to third party	0.105664	0.112918	0.143641	0.233863	0.25178	0.264213	0.03756	0.046692	0.059692
Small teams	0.516343	0.533	0.533	0.289987	0.301456	0.302	0.025418	0.034963	0.043423
Being single product	0.050268	0.056433	0.067675	0.029018	0.03897	0.058315	0.165	0.165	0.165
Low experience team	0.124554	0.168452	0.19603	0.214555	0.230515	0.242102	0.074757	0.082649	0.088449
Business plan	0.427064	0.430476	0.477874	0.247407	0.26169	0.290942	0.04269	0.055474	0.056869
Primary investment	0.346013	0.393769	0.418513	0.229312	0.238911	0.266298	0.045817	0.04764	0.054564
market	0.049919	0.076909	0.122307	0.058454	0.076646	0.096356	0.115646	0.114004	0.121806
Technical experience	0.093828	0.107046	0.155303	0.164444	0.173318	0.200454	0.052164	0.055414	0.054777
Process inefficiency	0.322288	0.340016	0.372761	0.030281	0.038369	0.055564	0.034836	0.036716	0.046612
Investment in research and development	0.055491	0.0718	0.091346	0.069698	0.072948	0.076139	0.130787	0.130889	0.137822
Financing	0.533	0.533	0.533	0.302	0.302	0.302	0.042284	0.041907	0.052883

Table 8. Weighted fuzzy normal matrix of WASPAS

Factors	Time			Cost			Quality		
	0.533			0.302			0.165		
Social network	0.177139	0.207352	0.238807	0.14602	0.172103	0.195118	0.164816	0.160931	0.165
Communication and strategies of marketing	0.240603	0.28625	0.299375	0.264003	0.293306	0.302	0.012419	0.01819	0.020933
Gain and loss	0.051213	0.100363	0.113907	0.231953	0.236848	0.259149	0.13712	0.14376	0.153221

Table 9. P fuzzy values

Factors	P1	P2	P3
Resource shortage	0.751792	0.796603	0.837461
Innovation	0.28567	0.340994	0.378159
Uncertainty	0.619723	0.662691	0.714156
Time pressure	0.73993	0.777368	0.801142
Quick changes	0.250253	0.274733	0.300917
Dependency to third party	0.377087	0.411391	0.467545
Small teams	0.831748	0.869419	0.878423
Being single product	0.244286	0.260403	0.29099
Low experience team	0.413866	0.481616	0.526581
Business plan	0.717161	0.74764	0.825686
Primary investment	0.621141	0.68032	0.739374
Market	0.224018	0.267559	0.340469
Technical experience	0.310436	0.335777	0.410535
Process inefficiency	0.387406	0.415101	0.474937
Investment in research and development	0.255976	0.275636	0.305307
Financing	0.877284	0.876907	0.887883
Social network	0.487975	0.540387	0.598925
Communication and strategies of marketing	0.517025	0.597746	0.622308
Gain and loss	0.420287	0.480971	0.526277

Q fuzzy values

Factors	Q1	Q2	Q3
Resource shortage	0.435816	0.19733	0.649877
Innovation	0.080522	0.137524	0.473633
Uncertainty	0.347103	0.192799	0.499653
Time pressure	0.531739	0.206142	0.144287
Quick changes	0.112006	0.094742	0.273645
Dependency to third party	0.118785	0.250409	0.190637
Small teams	0.528836	0.298725	0.138767
Being single product	0.057702	0.041319	0.66
Low experience team	0.164372	0.229422	0.328505
Business plan	0.441472	0.265432	0.210507
Primary investment	0.388016	0.243358	0.195662
Market	0.081511	0.077025	0.465459
Technical experience	0.115806	0.177883	0.217769
Process inefficiency	0.34377	0.040646	0.15488
Investment in research and development	0.072609	0.072933	0.530386
Financing	0.533	0.302	0.178981
Social network	0.207662	0.171336	0.651679
Communication and strategies of marketing	0.27812	0.288154	0.069732
Gain and loss	0.091462	0.241199	0.577861

Table 10. K value and final prioritization by fuzzy WASPAS method

Factors	P	Q	K
Resource shortage	2.385857	1.283022	1.83444
Innovation	1.004824	0.69168	0.848252
Uncertainty	1.99657	1.039556	1.518063
Time pressure	2.31844	0.882167	1.600303
Quick changes	0.825903	0.480393	0.653148
Dependency to third party	1.256023	0.559831	0.907927
Small teams	2.57959	0.966328	1.772959
Being single product	0.795679	0.759021	0.77735
Low experience team	1.422063	0.722298	1.072181
Business plan	2.290486	0.917412	1.603949

Table 10. K value and final prioritization by fuzzy WASPAS method

Factors	P	Q	K
Primary investment	2.040835	0.827035	1.433935
Market	0.832046	0.623996	0.728021
Technical experience	1.056748	0.511458	0.784103
Process inefficiency	1.277444	0.539296	0.90837
Investment in research and development	0.836919	0.675929	0.756424
Financing	2.642074	1.013981	1.828028
Social network	1.627286	1.030677	1.328982
Communication and strategies of marketing	1.73708	0.636005	1.186543
Gain and loss	1.427535	0.910522	1.169029

Table 10 presents the final prioritization of risks obtained using the fuzzy WASPAS method. The findings indicate that resource shortage and resource supply are identified as the most significant risks, followed by challenges related to small teams, time pressure, and business planning. Notably, uncertainty ranks in second place. It is important to emphasize that the primary objective of this research is not merely risk prioritization; rather, the scores derived from the fuzzy WASPAS with a k-value are utilized to optimize risk reaction strategies.

4.5. Risk response optimization using multi objective-mathematical model

In this section, we present the strategies and subsequently solve the mathematical model. The risk response strategies, grounded in active expert opinions from startups, comprise a total of 10 strategies, as detailed in Table 11.

Table 11. risk response strategies

No	Title of risk response strategy	Notation
1	Financing through micro capital	S1
2	Sponsor attraction	S2
3	Labor education through experience and capability increase	S3
4	Team making and task assignment	S4
5	Market international development	S5
6	Financing through banking loan	S6
7	Product development	S7
8	Manager's training based on start-up paradigm	S8
9	Exact recognition of opportunities inside and outside of country	S9
10	Innovation based on needs and issues	S10

The 10 risk response strategies outlined in the table above can be analyzed through the mathematical model to identify their allocation to specific risks and determine the optimal strategy. The results of the mathematical model for the current research are presented in Table 12. Table 12 presents the recommended assignments of risk response strategies to various risks, aiming to achieve both the lowest costs and minimal scheduling delays for startup projects. For instance, implementing labor training to enhance experience and capabilities addresses resource shortages effectively. International market development is identified as a suitable strategy for mitigating innovation risks and can also serve as a response to time pressure risks. Additionally, training managers in the context of startup paradigms helps manage dependencies on third parties, while financing through micro-capital addresses challenges faced by small teams. Moreover, team formation and task assignment, along with innovation driven by existing needs, are effective responses to single product risks. At the same time, attracting sponsors can resolve issues related to primary capital, and task assignments can support low-experience teams. Furthermore, innovation tailored to needs can effectively address primary capital concerns. It is important to note that multiple strategies may sometimes be applicable for responding to specific risks.

Table 12. Assignment of risk response strategies

Risks	Financing through micro capital	Sponsor attraction	Labor education through experience and	Team making and task assignment	Market international development	Financing through banking loan	Product development	Managers training based on start-up	Exact recognition of opportunities inside and outside of country	Innovation based on needs and issues
Resource shortage			✓							
innovation					✓					
uncertainty										
Time pressure					✓					
Quick changes										
Dependency to third party								✓		
Small teams	✓									
Being single product				✓						✓
Low experience team				✓						
Business plan										
Primary investment		✓								✓
market										
Technical experience										✓
Process inefficiency										
Investment in research and development										
Financing						✓				
Social network						✓				
Communication and strategies of marketing						✓				
Gain and loss							✓			

4.6. Practical implications

This research provides valuable insights for project managers by clearly identifying the most significant risks faced by startups and systematically determining optimal strategies for addressing these risks, with the objective of reducing both costs and execution time. Based on results of this paper, manager can decide about risk and plan strategies for encountering with them, Therefore the findings of this research can have practical application in world business.

5. Conclusion

In conclusion, this research emphasizes the importance of identifying, evaluating, and managing risks in startup projects using a hybrid approach that integrates statistical methods, SWARA, fuzzy WAPAS, and multi-objective mathematical modeling. The methodology begins with a robust risk identification process, followed by validation and quantification, leading to the weighting of risk measures across time, cost, and quality dimensions. Although the primary aim is not solely achieving risk prioritization, the scores produced are crucial for optimizing risk response strategies. The findings indicate that the most critical risks for startups include resource shortages and supply challenges, along with issues related to small teams, time pressure, and strategic planning, while uncertainty is a lesser concern. Effective risk response strategies identified include labor training to address resource shortages, pursuing international market development to alleviate innovation-related time pressures, and training managers to minimize third-party dependencies. Additionally, securing micro-capital financing can help mitigate risks tied to small teams, whereas team-building and task assignment, along with innovation aligned to market needs, can counter challenges arising from reliance on a single product. Attracting sponsors emerges as a viable strategy for securing initial capital, while effective team-building and task distribution can support teams with limited experience. Importantly, innovation driven by market demands can significantly alleviate initial capital constraints. This study illustrates that fostering an international development strategy that promotes innovation is effective in reducing risks associated with innovation. The suggested strategies highlight the value of managerial training in strengthening organizational capacity and decreasing reliance on external resources. Moreover, financing through micro-capital can eliminate various financial barriers. Diversification and innovation further enable startups to overcome vulnerabilities linked to dependence on a single product.Future research directions could include exploring alternative conditions for strategy assignment without considering cost and time, as well as prioritizing risk responses—a dimension not covered in this study, which concentrated primarily on optimization.

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References

Alawneh, R., et al. (2024). "Development of a New Method for Assessing Project Risks in Sustainable Building Construction Projects in Developing Countries: The Case of Jordan." Buildings 14(6): 1573.
Alvand, A., et al. (2023). "Identification and assessment of risk in construction projects using the integrated FMEA-SWARA-WASPAS model under fuzzy environment: a case study of a construction project in Iran." International journal of construction management 23(3): 392-404.
Andrić, J. M., et al. (2019). "Identifying the critical risks in railway projects based on fuzzy and sensitivity analysis: A case study of belt and road projects." Sustainability 11(5): 1302.
Antoniou, F. (2021). "Delay risk assessment models for road projects." Systems 9(3): 70.
Bepari, M., et al. (2024). "A comparative study of project risk management with risk breakdown structure (RBS): a case of commercial construction in India." International journal of construction management 24(6): 673-682.
Dandage, R. V., et al. (2018). "Analysis of interactions among barriers in project risk management." Journal of Industrial Engineering International 14: 153-169.
Erlita, A., et al. (2023). "Multiphase Project Risk Management on Food Factory Building Construction: Consultant Perspective." Journal of Construction in Developing Countries 28(1): 1-17.
Fauzi, S. N. M., et al. (2022). "A Review Paper on Risk Management of Start-up Business for Small Medium Entrepreneurs (SMEs)." The Journal of Management Theory and Practice.
Festel, G., et al. (2013). "Valuation of early stage high-tech start-up companies." International journal of business 18(3): 216.
Giardino, C., et al. (2014). "What do we know about software development in startups?" IEEE software 31(5): 28-32.
Gichohi, P. P., et al. (2024). "PROJECT RISK MANAGEMENT ON THE PERFORMANCE OF ROAD CONSTRUCTION PROJECTS IN KENYA." International Journal of Management and Business Research 6(1): 108-130.
Harrison, R. T. and C. M. Mason (2017). "Backing the horse or the jockey? Due diligence, agency costs, information and the evaluation of risk by business angel investors." International Review of Entrepreneurship 15(3): 269-290.
He, S., et al. (2024). "Systemic Risk Analysis of Safety, Progress, and Investment in the Construction of a Water Transfer Project and the Importance of Common Cause Failure." Water 16(10): 1454.
Karaarslan, M. H. and N. Soylu (2023). "Risk Factors in Start-Ups: An Evaluation." Selçuk Üniversitesi Sosyal Bilimler Meslek Yüksekokulu Dergisi 26(1): 241-258.
Khalilzadeh, M., et al. (2024). "A Step-By-Step Hybrid Approach Based on Multi-Criteria Decision-Making Methods And A Bi-Objective Optimization Model To Project Risk Management." Decision Making: Applications in Management and Engineering 7(1): 442-472.
Marle, F. (2020). "An assistance to project risk management based on complex systems theory and agile project management." Complexity 2020(1): 3739129.
Nge'tich, E. and R. Munene (2024). "Influence of project risk management practices on road projects in Nakuru County, Kenya." International Academic Journal of Human Resource and Business Administration 4(4): 163-197.
Nikolaenko, V. and A. Sidorov (2023). "Analysis of 105 IT project risks." Journal of Risk and Financial Management 16(1): 33.
Nunes, M. and A. Abreu (2020). "Managing open innovation project risks based on a social network analysis perspective." Sustainability 12(8): 3132.
Nunes, M., et al. (2021). "A model to manage cooperative project risks to create knowledge and drive sustainable business." Sustainability 13(11): 5798.
Polishchuk, V., et al. (2019). "A fuzzy model of risk assessment for environmental start-up projects in the air transport sector." International journal of environmental research and public health 16(19): 3573.
Qian, Q. and P. Lin (2016). "Safety risk management of underground engineering in China: Progress, challenges and strategies." Journal of Rock Mechanics and Geotechnical Engineering 8(4): 423-442.
Senova, A., et al. (2023). "New approaches to project risk assessment utilizing the Monte Carlo method." Sustainability 15(2): 1006.
Teberga, P. M. F., et al. (2018). "Risk analysis in introduction of new technologies by start-ups in the Brazilian market." Management Decision 56(1): 64-86.
Sarvenaz Heydarpour, Seyyed Hosein Seyyed Esfahani Behrooz Khorshidvand, Providing a DEA and AHP hybrid model to evaluate contractors' performance
((Case study: Zarand Iranian Steel Co. (ZISCO), ournal of Industrial Engineering and Management Studies, Vol. 9, No. 1, 2022, Pages 1-10
Mahmoud Rasouli, Ashkan Ayough, Behrooz Khorshidvand, Akbar Alemtabriz, Evaluating risk factors in solar energy investments: A strategic approach for Iran's market, Solar Energy Volume 262, 15 September 2023, 111884
Ashkan Ayough, Setareh Boshruei, Behrooz Khorshidvand, A new interactive method based on multi-criteria preference degree functions for solar power plant site selection, Renewable Energy Volume 195, August 2022, Pages 1165-117