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CASE STUDIES

Identifying and ranking risks using combined FMEA-TOPSIS method for new product development in the dairy industry and offering mitigation strategies: case study of Ramak Company

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Abstract Food industry as one of the most important and influential industries plays an important role in the health and well-being of the community. It is also important for the country's economy, export, and inter-state relations. As the industry expands and competition becomes tougher, the development of new products that can compete in this competitive market has become a major concern for manufacturers but the production of new products is always associated with uncertainties and risks, the management of which is the core of the new product development process and plays an important role in the success of industries. Risks occur in different shapes at every stage of the new product development process from design to consumption. In this study, the new product development process in a dairy company is investigated. A quantitative approach is proposed to identify and rank the risks affecting this process using the combined Failure Mode and Effects Analysis (FMEA) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. Shannon entropy method is also used to weight the criteria in the TOPSIS method. Identified risks by considering expert's opinion were scored from 0 to 10 regarding FMEA method factors (Severity, Occurrence, Detective), then by utilizing Shannon entropy method in TOPSIS each risk was weighted and ranked. 14 risks are first identified and then ranked based on 30 experts opinions from different parts of the company such as marketing, accounting, engineering, staff, management etc. and prior studies. The results show that 'Mismatching product Specifications with costumer needs and tastes' and 'The emergence of a new rival' are the most important risk factors for new product development. Risk reduction strategies based on the standard of project management, firm strengths and weaknesses and expert opinions on all risk factors are provided. At the end, some recommendations are provided to the managers of the company. The proposed approach is applied in Ramak Company and the results are approved by experts, more importantly, they are agree that the proposed approach can be used to identify, evaluate and present risk reduction strategies in the food industry.

Keywords Risks · Risk identification · Risk ranking · Risk reduction strategies · Development of new product · Food industry

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1 Introduction

As one of the most important industrial sectors of all countries, the food industry, plays an important role in creating employment, profitability, and income generation for each country's economy, ensuring health and food safety, and contributing to creating a dynamic society. In addition to catering to the needs of the food industry, it is also an essential part of exports in all countries. Due to the boom in the food industry and the competitiveness of markets, there are several companies operating in the food industry today, most of which are privately owned. These companies import a wide range of products into the domestic and foreign markets in their competition to gain a significant market share. According to statistics, about 3 percent of GDP is produced by the food industry, so the food industry can be considered a symbol of the country's economy and contribute to getting out of the recession. However, the industry faces capital sleep challenges, lack of quality segregation and competition between manufacturers complying with domestic and international standards with non-standard companies, and the need for fixed capital to modernize machinery (Industry Biography 2016).

The food industry in our country has also grown significantly in recent years, and this is an important business issue for Iran. The dairy industry is one of the most important and growing industries that has been studied in this research. Many companies are active in this field, and according to the Trade Promotion Organization of Iran, there are 641 functional units in the country, producing 5,500,000 tons of milk and dairy products (Iranian Business 2016). According to the World Food and Drug Administration in 2014, Iran ranks 51st globally, with exports of dairy products amounting to 0.7 billion dollars. According to the Presidential Office for Food, Drug, and Health Industries estimates, the figure will reach 977 million dollars if sanctions continue in 2006 and 1411 million dollars if sanctions are lifted (Iranian Business 2016). Considering the points mentioned earlier, the strengths and opportunities in the dairy industry of the country can be summarized as follows:

- Desirable quality of Iranian dairy products
- High availability and export share in Iraq market
- Growing neighbor country's taste in Iranian dairy products

The weaknesses and threats in the country's dairy industry are as follows:

- Rising feed prices
- Decrease in barley production due to drought
- The annual increase in input prices
- Failure to comply with the standard of goods at the outlet
- Increase in tariffs on exports of Iranian goods to Iraq

As an essential part of the food industry, new product development is defined as the process an organization considers using its resources and capabilities to create a new product or improve an existing product. New product development is when an organization considers using its resources and capabilities to create a new product or improve a current product. New product development is inherently associated with risk management (Stephen 2012). New product development processes are becoming more complex, so the risks associated with these processes have increased dramatically. While new product development is recognized as one of the riskiest measures by companies, their risk assessment techniques still need further investigation (Zavieh and Fekri 2014). More importantly, with the emerge of coronavirus (COVID-19), the function of all industries and systems affected by this unknown virus. Food industry as one the most critical industries in each country has faced new risk factor which has affected all part of the system and industry. the authors of (Zeina et al. 2021) investigated the impact of coronavirus on supply-chain sector of food industry as one of the critical sectors in food industry. They reviewed many researches in this field and provided significant suggestions to overcome this obstacle and risk for researchers and company's authorities. So, by considering this new pandemic, the need for risk assessing in food industry in order to mitigate the effects of this new risk in is felt more than ever.

There has been significant growth in new product development in academic and industrial fields (Lam and Chin 2005). Studies show the features that should be considered in new product offerings, such as customer needs and attention to market trends and technology development, have reduced the risk of new product launches. Paying attention to these features will increase responsiveness to customer needs and improve the business (Guide 2001). As companies continually need to develop new products to compete and grow, they always face many risks. The most critical barriers to new product development are the high cost of new product development processes and uncertainties associated with market acceptance and the support of senior executives (Ahmed et al. 2007). As population and income growth directly increase demand, supply-side demand has become a serious issue (Fartoukzadeh 2009). Therefore, food industry companies are developing new products to respond to customer needs and have a competitive advantage. In this regard, this study seeks to identify the risks of developing new products in a dairy company, rank them and develop risk reduction strategies to control the effects of them.

An essential point in the production and export of dairy products in the country is the market share of various companies. One way to expand the market share of new products is to be aware of the country's tastes and the target export countries. There are many problems in this area that need to be identified and scrutinized. Accordingly, examining the risks involved to avoid potential risks can also help the industry become more successful. In this regard, this study seeks to identify the risks of developing new products in a dairy factory and rank them and develop risk reduction strategies.

The company under study here is Ramak Company located 20 km from Shiraz on Shiraz-Bushehr Road. This company was established in 1995 and is active in dairy and ice cream production fields, producing about 70 dairy products, including milk, cheese, yogurt, buttermilk, cream, butter, and ice cream in 90 types. The company holds quality management, environmental management, occupational health, and food safety certifications from the Austrian Quality Austria Company and a Halal Certificate (The world of Economic 2014).

In this study, risks affecting new product development are identified using prior research and expert opinions. Then risk factors are rated using the combined FMEA and TOPSIS methods. Besides, the criteria weights are calculated by the Shannon entropy method, then the critical risks are determined, and mitigation strategies will be provided for all risk factors.

2 Literature review

The word risk has many meanings in the various articles and books that provide different definitions for their purpose (Guide 2001).In the newer and more general descriptions, the risk is defined as all possible consequences that can be predicted, and solutions are adopted for their likelihood of occurrence (Zhuo 2005). Considering the risk definitions and the fact that there are as many possible outcomes as possible risks, the types of identified risks identified and their prevention strategies should be considered. Risk is divided into two primary and secondary categories: Primary risks include incidents such as fires, scams, theft, etc. Organizations resort to insurance and preventive measures to prevent and compensate for such incidents. On the other hand, secondary risks involve starting a company or entering the market and developing new products (Stephen 2012). Nevertheless, risk means uncertain results of an action, which can be either positive or negative. So, there is another classification that divides risks into speculative and dangerous risks. Speculative risks are associated with an improvement or profitability, while dangerous risks are related to events with a probability of loss (Zavieh and Fekri 2014).

Risk management was introduced as a science in the 16th century, and various project risk management models were introduced in 1990 to increase the likelihood of project success (Guide 2001). The risk management process is also a systematic process for planning, structuring, analyzing, responding to project risks, control, and manage them (Lam and Chin 2005). Over the years, risk management has been developed into a new structure. Table 1 outlines some steps in introducing risk management and its evolution.

In general, the project risk management process consists of two broad stages of risk assessment and response. There are several methods used to identify project risks, each being used in specific circumstances. The main ways to identify risks include brainstorming, reviewing documentation, the Delphi technique, checklist analysis, and hypothesis analysis (Barry 1991). After identifying the risks, another critical issue is analyzing their mitigation strategies. Risk analysis is performed both qualitatively and quantitatively. Qualitative risk analysis usually involves probability assessment, impact, and probability-impact matrix. Quantitative analysis uses sensitivity analysis, expected monetary value analysis, decision trees using utility theory, simulation, cause and effect diagrams, game theory, fuzzy theory, and error tree analysis (Dorri and Hamzehi 2010). After analyzing the risks, it is necessary to take possible preventive and reactive measures. A preventive response initially targets the likelihood of risk occurrence, but a reactive response focuses on mitigating the effects of the risk after its occurrence After analyzing the risks, it is necessary to take possible preventive and reactive measures. A preventive response initially targets the likelihood of risk occurrence, but a reactive response focuses on mitigating the effects of the risk after its occurrence (Lee 2009). Barghi and Shadrokh, in their research, presented a qualitative and quantitative project risk assessment using a hybrid PMBOK model developed under uncertainty. They found 32 risk factors, and their number reduced to 17 risks using the expert opinions via the fuzzy Delphi technique run through three stages. Then the identified risks were structured and ranked using fuzzy DEMATEL and fuzzy ANP techniques (Behrad et al. 2020). In another study, Aven reviewed the literature on risk management and concluded that the scientific basis of risk assessment and risk management still needs to be further tested and developed in some respects and some cases, including the emergence of social and technological problems (Terje 2016). Sardar et al. researched the crude oil transmission line using the FME and CE method for risk assessment. Their results indicated that the risk of failure due to improper maintenance is low (Ali et al. 2009). Hajimolaali et al. identified more than 100 main quality risks. Twenty of the identified risks are recognized as practical risks in the industry. Risks survey results could point to the prominence of the quality assurance unit and its vital but partially neglected role in the generic pharmaceutical industry (Hajimolaali et al. 2017). Giannakis et al. have considered sustainable supply chain operational process as a risk management process, focusing on three environmental, social, and economic indicators as three pillars of sustainability. Their study was conducted in two textile companies using the FMEA method. Their results illustrated the most desirable sustainability in therapeutic

Table 1 Risk management introducing steps and its evolution (Guide 2001)

Model	Explanation	Year
Pert structure	The first method of risk planning was using a network-based model of activities that had time and estimates	1950
Probability model of decision tree	This model is derived from the Markov process, and processes are defined at different times	1960
9-steps model	This model is intended to develop and guide risk management based on the experiences gained by an English organization	1990
Fairley model	The model consists of 7 phases, including 1- Identifying risk factors, 2- Estimating the probability of occurrence and extent of the impact, 3- Providing strategies to reduce the identified risks, 4- Monitoring risk factors, 5- Presenting contingency plans, 6- Crisis management, 7- Post-crisis organization resuscitation	1994
6-Phases model	Project Management has introduced six phases in its Guide to Knowledge-Based Project Management.1-Risk Management Planning, 2- Identification, 3-Qualitative risk analysis, 4-Quantitative risk analysis, 5-Risk response planning, 6-Risk monitoring and control	2000
Boehm model	In this model, risk management consists of two main phases of risk estimation and risk control	2001

strategies risk, and environmental risk requires integrated risk management (Giannakis and Papadopoulos 2016). Chang et al. proposed a hybrid FMEA and multi-attribute decision-making (MADM) model to establish an evaluation framework, combining the rough best-worst method (R-BWM) and a rough technique for order preference based on their similarity to an ideal solution technique (R-TOPSIS) to determine the improvement order of failure modes. Their results showed that the proposed model could overcome many shortcomings of traditional FMEA and electively assist decision-makers and R& D departments in improving the reliability of products (Tai-Wu et al. 2019) Rodriguez et al. have developed a method for selecting appropriate risk management for information technology projects that uses fuzzy hierarchical analysis to evaluate models. They created a new model that was less costly than previous models (Rodriguez et al. 2017). Subsequently, Talluri et al. investigated the risk management strategy in terms of transport capacity. They used three risk-reduction strategies in this field using industry-based data and examined the two factors of cost and demand (Yoon et al. 2016). Amiri et al. ranked risks in a project using the two cost and time criteria to rank activities, incorporating the time criterion to evaluate the buoyancy derived from the CPM network in their model and expert cost criteria. They also used expert opinion for cost factors and assessed risk activities using AHP (Analytic hierarchy process) (Maqsood et al. 2009). Hamzehi and Dorri, using a project management standard, performed a case study at the Oil Company Engineering and Development Company on the Azadegan Oil Field Development Project. They used ANP techniques to investigate the problem of selecting answers from several solutions relating to one risk. First, the main project risks were identified through a questionnaire, and then response strategies for specific critical risks were prepared. Finally, the decision-making model was selected using prior research and nominal group technique, and the best strategies were selected through paired comparisons (Dorri and Hamzehi 2010). Ben-David et al. focused on the interaction of project work-flows for risks and risk reduction measures and presented a branch and bound optimization algorithm and two innovative algorithms. The proposed model links project elements, risks affecting factors, and a set of risk mitigation measures. The impact of risk events on the aspects of work was calculated in terms of monetary loss, and the objective function was developed to minimize the total expected costs associated with the risks, including the two parts of the costs of risk mitigation measures and the anticipated risks of losses (Ben-David and Rabinowitz 2002). Baynal et al. indicated that implementing corrective/preventive activities resulted in a 96 percent improvement in door seal cuts problem caused by the doorstep assembly. The door seal cuts problem caused by instrument panel assembly and the noisy door window problem were solved completely (Baynal et al. 2018). In the work of Safari et al., because of some drawbacks of the traditional FMEA, risk factors with fuzzy VIKOR were prioritized instead of calculating Risk Priority Number (RPN). The proposed method was used for evaluating twenty EA risk factors to integrate knowledge and experience acquired from professional experts (Safari et al. 2014). COVID-19 pandemic has been recently entered in the literature of risk management. Because of the importance of this pandemic and its negative effects on risk management area, some researches which investigated the this pandemic and its impact are reviewed and will present in the following. Authors of (Anish et al. 2021) developed a model to assess the risks of coronavirus on biomass supply-chain. The results showed that at least one year need to recover the negative impacts of COVID-19 to the biomass supply-chain. Their model showed the accuracy of 95 percent which means the coronavirus definitely impact the sustainability of biomass feedstock. In (Anish et al. 2021) authors identified and ranked risk reduction strategies for perishable food supply chains using fuzzy-best worst methodology. All strategies provided by considering COVID-19 pandemic's socio-economy effects on this sector.

The development of new products is one of the measures used by organizations and is always associated with various risks. A product has defined features, functions, and benefits that can be used or exchanged as a mix of tangible and intangible forms. Each product has a life cycle which is a process that goes from idea design to destruction in four stages: 1- Product introduction, 2- Growth, 3- Maturity, 4- Decline. At the introductory stage, sales growth is slow and continues until there is complete and sufficient knowledge of the product. At the growth stage, sales accelerate as the product gains acceptance in the community. At the maturity stage, product growth stops, and the product gains prominence among buyers. Product sales decline at the decline stage as either the product has fallen out of favor with consumers or an alternative product has been introduced (Philip and Gary 2010). At the deterioration stage, sales will suffer some difficulties for some reason. One way to deal with this problem is to develop new products. Some of the reasons companies create new products include: the importance of growing organizations, raising awareness, advancing technology, increasing competitors, changing customer tastes, retaining current customers, attracting new customers, and gaining more market share in the heavily competitive marketplace (Suwannaporn 2010). The historical evolution of new product development process definitions are presented in Table 2.

The new product development process includes organizing, concept production, marketing, evaluation, and commercialization. One of the crucial issues in the new product development process is the risks and uncertainties that make organizations hesitant to develop and expand markets. These uncertainties include uncertainties in technology, markets, and competitive fluctuations (Buyukozkan and Feyzıoglu 2009). One of the risks that may jeopardize organizations' new product development is how new technologies affect the product development process. This is mainly due to the inability of the customer to express their needs as well as managers' problems with technological developments and their impact on features of the new product (Son 2005). In another study, the risks affecting the development process of new products are divided into research and development, commercialization, and marketing. Another type of risk is a technological risk, which refers to potential risks during the technical development phase, including technical, financial, research and development, and personnel risks. Commercialization risk refers to potential research findings, and ultimately market risk involves market uncertainty (Song et al. 2013). To determine the potential risks in developing new products, Sowlati et al. used the AHP approach to weight the selection criteria and data envelopment analysis to prioritize information projects and finally provide a model for ranking them (Sowlati 2005). The outcome of Chauhan et al. study revealed two high, three moderate, three low, and one negligible risk source. A risk alleviation strategy framework was suggested to propose risk mitigation measures for the automotive new product development process for the aid of engineering managers (Buyukozkan and Feyzıoglu 2006). The outcome of Chauhan et al. study revealed two high, three moderate, three low, and one negligible risk source. A risk alleviation strategy framework was suggested to propose risk mitigation measures for the automotive new product development process for the aid of engineering managers (Chauhan et al. 2017)

Table 2 New product development steps and its evolution (Zavieh and Fekri 2014)

Researcher	Explanation	Year
Doqerti	Knowledge consisting of a set of activities performed in an organization	1990
Vill wright and Klark	A set of activities and strategies for generating growth at different stages of product production leading to change	1992
Dryzher	Activities transmit instructions, customer order, market demand, and technological advancement into the design and production process	1993
Griffin	Using a formal process that is dependent on the success and failure factors of the product	1997
Polton et al.	New product development is recognized as a key process of competition in a variety of different markets	1998
Cooper	Activities and strategies to generate growth that will lead to changes or refinements in the market at different stages of product production	1999
Song	An important endeavor in today's competitive environment	2006
Honger et al.	Includes all activities from developing an idea or concept to realizing a product at the production stage and introducing it to market	2007

Kayis and his colleagues developed a new approach to reducing new product development and design risks in concurrent engineering projects. Their approach involves identifying and quantifying risks in the product life cycle (Kayis and Arndt 2007). Mahmoodzadeh et al. developed a judgment matrix to evaluate new product development risks using AHP and fuzzy theory to illustrate the fuzzy judgment of decision-makers. They also used TOPSIS to rank risks (Mahmoodzadeh et al. 2007). The risks were classified using five computational and heuristic algorithms in three simulated scenarios. Finally, several solutions were presented that could be utilized to mitigate these risks (Kayis and Arndt 2007). Vahyudin and Santoso identified 27 risk factors for the product development of the yogurt drink at CV. XYZ. Three were selected as the risks that need immediate handling based on the Pareto diagram. Eleven mitigation strategies were obtained to be applied in product development of yogurt drink at CV XYZ (Nur Eko 2016). Rabei et al. identified and ranked new product development challenges in knowledge-based companies using the AHP method. According to the results, marketing research as the most critical and inaccurate estimation of the target market is the least important challenge (Ali et al. 2011). Kirkire et al. analyzed risks in medical product development using traditional Failure mode and effect analysis (FMEA) and fuzzy FMEA. A comparison of the results yielded by the two methods showed that the fuzzy approach avoids the duplication of RPNs and enables converting the knowledge of experts into information to get values of risk factors (Milind Shrikant 2015). Wang and Lin proposed a model for scheduling risks in new product development. They analyzed the impact of the process structure on the delivery time of a new product development project and used a developed simulation algorithm to analyze it (Wang 2009). Goodwin investigated the customer perceptual risk in product development using a multidimensional linear approach using a two-factor model. This research offers a quantitative approach to testing new product development (Goodwin 2009).

U.S. National Aeronautics and Space Administration (NASA) first introduced FMEA in the 1960s. FMEA helps understand product failure modes, qualify the effects of failure, and develop mitigation strategies. It is also a valuable tool in improving quality, reliability, and the maintainability of designs and functions as a critical component in risk management strategies and assessments. The authors in (Toljaga-Nikolić et al. 2018) proved that FMEA is a valuable tool to identify, prevent, eliminate, and control potential project errors. In (Shirani and Demichela 2015) a risk assessment tool (FMEA) integrating the Human Factor along the food production supply chain was applied, and the method was used for dairy production. They concluded that the human factor is the most crucial cause of risks, and these human risks are not covered by classical analytical validation. The technique for order preference by similarity to ideal solution (TOPSIS), proposed by (Hwang and Yoon 1981) is one of the well-known Multiple Criteria Decision Making (MCDM) methods applied to various engineering and management fields. An advanced FMEA method combined with interval 2-tuple linguistic variables (ITLV) and TOPSIS were used in (Guo-Fa et al. 2019). The assessments provided by different FMEA members based on their different linguistic term sets are represented by ITLVs. A comparison of the ITLV-GRA, ITLV-VIKOR and traditional methods was performed to confirm the proposed ITLV-TOPSIS method. In the work of (Certa et al. 2018) a quantitative risk assessment approach was employed based on Hazard Analysis and Critical Control Point (HACCP) and (TOPSIS) to individuate the production process and perform corrective actions to improve the consumer's safety in the smoked salmon manufacturing process of an authentic Sicilian industry. In another study (Chang et al. 2014)TOPSIS and DEMATEL methods were combined to rank the risk of FMEA failure. Their results showed that the proposed method could solve the drawbacks of the conventional RPN method. The final ranks obtained by the proposed method presented a more accurate risk ranking to assist managers in finding the most critical causes of failures and improving serious risk alternatives. A maintenance planning framework was developed in (Selim et al. 2016) using TOPSIS and FMEA techniques to reduce and stabilize the maintenance costs of the manufacturing companies. The authors implemented their framework to an international food company to confirm the viability of the proposed method. The results showed that the proposed method could effectively be used in practice. A hybrid approach based on support vector machine and fuzzy inference system was applied in (Mangelia et al. 2019) to decrease the effect of personal views in determining the severity and occurrence of risks. Also, Logarithmic Fuzzy Programming was used to determine the crisp weight of the dependent factor of FMEA, and the fuzzy TOPSIS was employed to rank risks. The results showed that this model is useful to predict severity and occurrence of risks in occupational accidents. In (Şenel et al. 2018) risks in ports in the maritime industry were assessed using the FMEA Based Intuitionistic Fuzzy TOPSIS Approach. The results showed that FMEA-based IF-TOPSIS is useful for this area.

In Table 3 the summary of researches on risk management and new product development are shown.

The FMEA and TOPSIS methods used in all the above papers confirm the effectiveness of these methods in risk assessment in different areas and industries. Also, as discussed above, previous research addresses risk assessment

Table 3 Summary of research on risk management and new product development

Researcher	Research method	Description	Features	Vacancies
Feyziogglu (2006)	Neural Network and Fuzzy Theory	Analysis of new product development project using neural network and fuzzy theory	1-Accelerating the evaluation process. 2-Ease of risk analysis process	Choosing risk factors only using previous work, not by experts interview
Arndt et al. (2007)	Using Innovative and computational algorithms	.	1-Identifying risks. 2-Quantifying risks using 5 computational algorithms and simulating them in 3 senarios. 3-Providing solutions for reducing risks	High costs and time consuming
Mahmoodzadeh and Pariazar (2007)	Using AHP, fuzzy theory and Topsis	1-Providing a new method for choosing alternative investment projects. 2-Demonstrating the fuzzy nature of decision makers' judgments	High operation speed, lower cost, rapid projects evaluation	Using AHP, fuzzy theory and Topsis
Wei (2011)	Combining the fuzzy theorem and MCDM	Deciding on choosing a new product development method based on three factors: performance, delivery, and risk	.	Lack of risk ranking
Zandi et al. (2020)	Using FMEA and Topsis	The expand the application of FMEA in risk management for agriculture projects	Using new FMEA method instead of old method	lack of risk reduction strategies
Moreira et al. (2020)	Using FMEA	Using FMEA in new product development at a hydro-sanitary company	Using an AR method using collaborative approach between industry and university	Lack of attention to risk classification based on company departments
Lo et al. (2021)	Using multi-objective mathematical model	Providing a model using risk management for supply chain (SC) configuration in new product development	.	High cost, Time consuming, lack of using a company for better demonstration of model performance
Sabzevari et al. (2020)	Using FMEA and Topsis	Providing model for assessing products and systems risks	Risk assessing using MCDA	.
Current research	Risk ranking using FMEA and TOPSIS	Investigating risk management process of new product development in Ramak company	1-Identifying risks 2-Risk ranking 3-Risk classification with considering different part of the company 4-providing risk reduction strategies	.

and new product development. However, the integration of FMEA and TOPSIS methods as two well-known methods for risk assessment in new product development has not been considered in any of them, particularly, in the Food industry in Iran. This turned out to be our encouragement for preparing the current work. In general, the main contributions of this work can be expressed as follows:

1. The new product development process in a food company is investigated for the first time in Iran.
2. A quantitative approach is proposed to analyze the risks affecting this process using the combined FMEA and TOPSIS methods as the well-known methods for risk assessment.
3. Shannon entropy method is used to weight the criteria in TOPSIS.
4. Several risk reduction strategies are proposed based on the standard of project management, firm strengths, and weaknesses, and expert opinions on all risk factors.

The rest of this paper is organized as follows. Section 3 states the research problem. The results of the data analysis are presented in Sect. 4. Finally, the conclusion of this paper is provided in Sect. 5.

3 Methodology

3.1 Study approach

Risks affecting the process of new product development in the food industry were identified using prior studies and expert opinions and then ranked using the Combined Failure Factors Analysis and their Effects (FMEA) and TOPSIS. FMEA is an engineering technique recommended by international standard systems such as ISO 9000, ISO.TS 16949, CE, and QS9000, to identify and eliminate potential errors, problems in systems, manufacturing processes, and services before the product is delivered to the customer. It was first used in the US aerospace industry in the 1960s and then in the 1970s and 1980s for atomic installations and has been used in the automotive industry from 1977 onwards. Since 2000, FMEA has been one of the most widely used risk assessment methods in all industries (Vahdani 2015). In the traditional FMEA approach to prioritizing failure modes, an index called the RPN is used, which is obtained by multiplying the effect severity, probability, and detection ability. Experts make judgments about the number of criteria. Some of the shortcomings of the FMEA method are 1- duplicate numbers and 2- disregarding criteria weights. TOPSIS is one of the multiple decision-making methods used in some research to address the FMEA method's shortcomings (Chang et al. 2014) (Sachdeva et al. 2009), which allows the use of different criteria, weighting, and ranking based on similarity to the ideal solution. The Shannon entropy calculates the weight of the criteria for measuring the risk factors, and the critical risks are determined. Then, using expert opinions, some solutions are suggested to reduce the risks. Following are the steps of the proposed approach to managing new product development risks in the food industry.

3.2 Identifying failure modes and causes

ThThe first step in the FMEA method is to identify the causes of failure. The risk identification process is the most important step that enables measurement and involves identifying the risks affecting the project and documenting their characteristics (Kudiakc et al. 2017). In this study, with the use of past researches, expert opinion polls, and finally interviews with senior executives of the organization, the failure states for new product development are identified.

3.2.1 Grouping the causes of failure based on company's segments

Projects face different types of risks that cannot be evaluated comprehensively and need to be divided into smaller groups for better management (Marle 2002). At this stage of the study, risk factors are classified according to different organizational units. This may help to select the responsible person(s) or units for each of the factors. It also allows for a more accurate assessment of the risks, and the person(s) responsible for the occurrence of risks can be held accountable for the consequences.

3.3 Scoring criteria for risk measurement factors using FMEA method

Criteria for measuring risk factors are: (1) probability of occurrence (O), (2) the severity of effect (S), and (3) the ability to detect (D). The probability of occurrence determines the probability of any of the causes of failure. The severity of the effect reflects the risk impact, and the ability to detect a factor's predictive power before it occurs. Each of the risk assessment criteria is scored on a scale of 0–10. Higher values indicate a more adverse effect of factors on the system. Tables 4, 5, 6 provide guidelines for scoring. At this point, the experts' opinions on each factor's ratings will be collected and averaged if any of the options are implemented. If there is a great deal of inconsistency between the experts, they will try to bring the comments closer.

3.4 Risk factor ranking using TOPSIS method

In TOPSIS, the best option has the closest distance to the positive ideal solution and the longest distance to the ideal negative solution. To use this method, first, the relative importance of the criteria is determined using expert opinion, and then the performance of each option is evaluated against each criterion (Momeni et al. 2017). One of the advantages of this method is that the criteria or indicators used for comparison can have different units of measurement and be either negative or positive. In other words, both negative and positive indicators can be used in this technique (Shukla et al. 2017). All the measurement factors in this study are negative, as higher values represent

Table 4 Guidelines for determining the risk factors (Sachdeva et al. 2009)

Score	Probability of occurrence	Percentage (%)
1	Impossible	Very low
2	Very unlikely	< 10
3	Unlikely	10–20
4	Very	20–30
5	Low	30–40
6	Medium	40–50
7	Upper than medium	60–20
8	High	60–70
9	Very High	70–80
10	Very Very High	> 80

Table 5 Guidelines for measurement criteria of ability of detection (Sachdeva et al. 2009)

Score	Description	Probability of indeterminacy (%)
1	The risk is recognizable before any study	Very low
2	Risk can be identified through research	< 10
3	By reviewing similar projects early in the planning, risk can be identified	10–20
4	The risk is identifiable at the planning and pre-implementation stages	20–30
5	At the start of the project, the risk is clearly identifiable	30–40
6	Risk can be identified by studying at the beginning of the implementation phase	40–50
7	At the mid-stage of the project implementation, the risk is shown	50–60
8	At the late stage of project implementation, the risk is shown	60–70
9	The probability of risk detection is low	70–80
10	Risk is unpredictable	> 80

Table 6 Guidelines for the severity of the effect (Sachdeva et al. 2009)

Score	Factor	Severity of effect
1	It does not have much impact on the purpose of the project	None
2	Makes minor changes to the purpose of the project	Very insignificant
3	It makes some significant changes, but it is not that harmful	Insignificant
4	Causes negative and effective changes in the purpose of the project	Very low
5	Has medium impacts on the project goal and increases time and cost	Low
6	Has significant impact on purpose	Medium
7	Causes waste of time and cost and redirect the project	Intense
8	The direction of the project has changed, and several activities have failed	Very Intense
9	9 In general, the project should be redesigned	Very dangerous with the danger announcement
10	The project will not be completed, and all previous work will fail	Very dangerous without the danger announcement

more undesirable effects on the system. First, the assessment Risk Matrix Z (1) is established for each factor. It consists of P options (risk factors) and three criteria (the probability of occurrence, ability to detect, effect severity). Z matrix is normalized using (2) and (3) and values (the distance from the positive ideal solution) and (the distance from the negative ideal solution) which are calculated using Eqs. (5), (6), (7), (8). The rank of the risk of each factor is calculated by (9). Also, the higher the risk rating, the less negative the risk effect.

$$z = [x_{ij}] \quad \forall i = 1..P, j = 1..5 \tag{1}$$

$$U = [u_{ij}] \quad \forall i = 1..P, j = 1..5 \tag{2}$$

$$u_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{p} x_{ij}^2}} \tag{3}$$

$$V = [v_{ij}] \tag{4}$$

w_j indicates the weight of factors and matrix V is a normal decision matrix that

$$\sum_{j=1}^{5} W_j \quad , v_{ij} = w_j * u_{ij} \tag{5}$$

$$A^+ = [min \quad v_{ij} | i = 1..p] = [v_1^+, .., v_p] \tag{6}$$

$$A^- = [min \quad v_{ij} | i = 1..p] = [v_1^-, .., v_p] \tag{7}$$

A^+ is a positive ideal value and A^- is a negative ideal value (Vahdani 2015) (Chang et al. 2014) (Sachdeva et al. 2009).

$$d_i^- = \sqrt{sum_{j=1}^5 (v_i j - v_j^-)^2} \tag{8}$$

$$d_i^+ = \sqrt{sum_{j=1}^5 (v_i j - v_j^+)^2} \tag{9}$$

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{10}$$

3.5 Risk reduction strategies

The project management standard provides four strategies for responding to negative risks Table 7 and four strategies for positive risks Table 8 (Guide 2001).

Both active and passive acceptance strategies can respond to both types of risk (positive and negative). When taking risks, strategies are taken to deal with them. This is known as Active Acceptance. However, if no provision is made, acceptance is passive.

4 Data analysis

4.1 Industry and product of under investigation

The study is conducted at Ramak Company, a manufacturer of dairy products near Shiraz. The company has recently planned to introduce new products, including 1-liter AGE milk, vegetable cheese, 300 g yogurt, EFL bottle milk, and Paprika Mix cheese. In this study, the risk management of Paprika cheese production is investigated.

4.2 Identifying the causes of failure

At this stage, through a review of the literature, 30 experts in the field and the organization's senior executives were interviewed. Then, the failure modes for new product development in the food industry, especially in the dairy industry, were identified. The identified risk factors were divided into 14 categories, as shown in Table 9.

4.3 Grouping causes of failure by company's segments

Table 10 shows the segmentation of the causes of failure by the company's sectors. One factor may be related to more than one sector.

4.4 Collecting risk factors scores using FMEA

The Risk Management Team includes the CEO, the Production Manager, the Marketing and Sales Manager, the R&D Unit, and the Quality Control Expert. By reviewing the causes of failure listed in Table 9, the team members expressed their views on measurement criteria scores and were averaged to aggregate opinions. In cases where opinions differed significantly, they tried to bring their comments closer together by discussion. The Risk Assessment Matrix, which calculates the ranking of the risk factors and consists of 3 criteria (The probability of occurrence, Ability of detection, and Severity) and 14 options (the risk factors), is formulated as shown in Table 11.

4.5 Calculating the weight of risk factor measurement criteria by Shannon entropy

The weight of the criteria is calculated using the Shannon entropy method, as displayed in Table 12. They are all negative because higher values indicate a more adverse effect on the system. The higher the values of a single criterion for different options, the more the weight that is given to that criterion. According to Table They are all

Table 7 Strategies for responding to negative risks (Guide 2001)

Strategy	Definition
Reduction	Reducing the probability or consequences of a risky event to an acceptable threshold
Transition	Transferring the outcome of a risk together with the ownership of its response to a third party
Avoidance	Change the project plan to eliminate the risk or maintain the project objectives from the impact of the risk
Acceptance	Failure to change the project plan in the face of a risk

Table 8 Strategies for responding to positive risks (Guide 2001)

Strategy	Definition
Improvement	Increase the probability risk occurrence
Exploitation	Providing the chance for realization of the opportunity to ensure its realization
Sharing	Collaborate with other companies or teams to realize opportunities because of the lack of capacity to realize the opportunity
Acceptance	Risk acceptance without change in programs

Table 9 Failure modes of the new product development process in the food industry

Row	Failure modes
1	Lack of access to raw materials
2	Delay in meeting market needs
3	Lack of liquidity
4	The emergence of a new rival
5	Market volatility
6	6 The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market
7	Mismatching product specifications with customer needs and tastes
8	Initial false tension of the product on the market
9	Change the sales volume in different seasons
10	Incorrect estimation of the need for product production to use modern equipment
11	Unbalanced product pricing
12	Decay of product during shipment and storage
13	Lack of skilled staff
14	Disregarding the proper weight and quantity in the initial product packaging

Table 10 Segmentation of causes of failure by company's sectors

Sector	Risk Factor
Management	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market
	Lack of liquidity
	The emergence of a new rival
	Unbalanced product pricing
	The emergence of a new rival
Production	Lack of access to raw materials
	Delay in meeting market needs
	Incorrect estimation of the need for product production to use modern equipment
	Disregarding the proper weight and quantity in the initial product packaging
Sales and Marketing	Mismatching product specifications with customer needs and tastes
	Delay in meeting market needs
	The emergence of a new rival
	Initial false tension of the product on the market
	Changing the sales volume in different seasons
	Unbalanced product pricing
Finance & Accounting	Lack of liquidity
	Unbalanced product pricing
Research & Development	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market
	Mismatching product specifications with customer needs and tastes
	The emergence of a new rival
	Incorrect estimation of the need for product production to use modern equipment
Human Resource	Lack of skilled staff
Quality Control	Disregarding the proper weight and quantity in the initial product packaging
	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market
	Decay of product during shipment and storage
Transportation	Decay of product during shipment and storage

Table 11 Average Comments on risk factor measurement criteria scores

Row	Risk	Probability of occurrence	Ability of detection	Severity of effect
1	Lack of access to raw materials	3.4	3.4	3
2	Delay in meeting market needs	2.2	6.4	3.4
3	Lack of liquidity	3.2	7.6	4.2
4	The emergence of a new rival	7.2	5.6	6
5	Market volatility	4.8	4.4	4.6
6	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	7.6	8.2	3
7	Mismatching product specifications with customer needs and tastes	7.8	9	6
8	Initial false tension of the product on the market	3.2	4.4	3.2
9	Changing the sales volume in different seasons	1.4	3	2
10	Incorrect estimation of the need for product production to use modern equipment	1.8	5.4	2.2
11	Unbalanced product pricing	5.6	8	5
12	Decay of product during shipment and storage	1.6	9.2	4
13	Lack of skilled staff	2	5.2	4.4
14	Disregarding the proper weight and quantity in the initial product packaging	2.2	3.2	4.4

Table 12 Weight of risk factor measurement criteria

Criterion	Probability of occurrence	Ability of detection	Severity of effect
Type of criterion	Negative	Negative	Negative
Weight	.598	.202	.200

Table 13 Normal matrix of mean of scores of risk factors measurement criteria

Row	Risk	Probability of occurrence	Ability of detection	Severity of effect
1	Lack of access to raw materials	0.204	0.2	0.325
2	Delay in meeting market needs	0.132	0.226	0.26
3	Lack of liquidity	0.192	0.28	0.309
4	The emergence of a new rival	0.432	0.4	0.228
5	Market volatility	0.288	0.306	0.179
6	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	0.456	0.333	0.2
7	Mismatching product specifications with customer needs and tastes	0.468	0.4	0.366
8	Initial false tension of the product on the market	0.192	0.213	0.179
9	Changing the sales volume in different seasons	0.084	0.133	0.122
10	Incorrect estimation of the need for product production to use modern equipment	0.108	0.146	0.22
11	Unbalanced product pricing	0.336	0.333	0.325
12	Decay of product during shipment and storage	0.096	0.266	0.374
13	Lack of skilled staff	0.12	0.211	0.293
14	Disregarding the proper weight and quantity in the initial product packaging	0.132	0.13	0.16

negative because higher values indicate a more adverse effect on the system. The higher the values of a single criterion for different options, the more weight given to that criterion. According to Table 12 the probability of occurrence with a weight of 0.598 is more important than the other two criteria, and the other two factors are almost equally important.

Table 14 Weighted-Normal matrix of mean of scores of risk factors measurement criteria

Row	Risk	Probability of occurrence	Severity of effect	Ability of detection
1	Lack of access to raw materials	0.122	0.066	0.04
2	Delay in meeting market needs	0.079	0.053	0.045
3	Lack of liquidity	0.115	0.062	0.056
4	The emergence of a new rival	0.258	0.046	0.08
5	Market volatility	0.172	0.036	0.061
6	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	0.273	0.067	0.04
7	Mismatching product specifications with customer needs and tastes	0.28	0.074	0.08
8	Initial false tension of the product on the market	0.115	0.036	0.043
9	Changing the sales volume in different seasons	0.05	0.025	0.027
10	Incorrect estimation of the need for product production to use modern equipment	0.065	0.044	0.029
11	Unbalanced product pricing	0.201	0.066	0.067
12	Decay of product during shipment and storage	0.057	0.076	0.053
13	Lack of skilled staff	0.072	0.043	0.059
14	Disregarding the proper weight and quantity in the initial product packaging	0.079	0.026	0.032

Table 15 Positive and negative ideal values

Criterion	Probability of occurrence	Ability of detection	Severity of effect
Positive ideal	0.05	0.027	0.025
Negative ideal	0.28	0.08	0.076

Table 16 Proximity to ideal option

Row	Risk factor	Distance to positive ideal	Distance to negative ideal	Proximity to ideal option
1	Lack of access to raw materials	0.084	0.163	0.66
2	Delay in meeting market needs	0.044	0.205	0.823
3	Lack of liquidity	0.08	0.167	0.676
4	The emergence of a new rival	0.216	0.037	0.146
5	Market volatility	0.127	0.117	0.48
6	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	0.227	0.042	0.156
7	Mismatching product specifications with customer needs and tastes	0.241	0.002	0.008
8	Initial false tension of the product on the market	0.068	0.174	0.719
9	Change the sales volume in different seasons	0	0.241	1
10	Incorrect estimation of the need for product production to use modern equipment	0.024	0.223	0.903
11	Unbalanced product pricing	0.161	0.081	0.335
12	Decay of product during shipment and storage	0.058	0.225	0.795
13	Lack of staff skills	0.043	0.212	0.831
14	Disregarding the proper weight and quantity in the initial product packaging	0.029	0.213	0.88

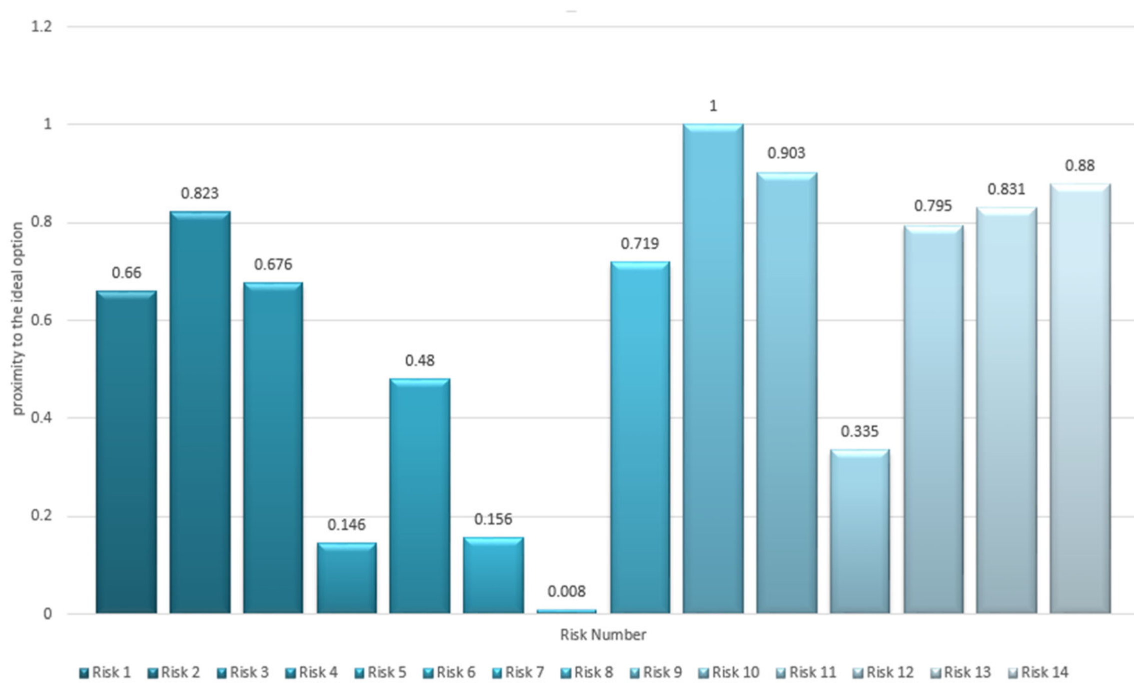

Fig. 1 Proximity of risk factors to the ideal option

4.6 Ranking of risk factors using FMEA and TOPSIS combined methods

Weighted-normal and normal matrices of mean scores of risk factors measurement criteria are shown in Tables 13, 14.

Positive and negative ideal values are shown in Table 15.

The distance to positive and negative ideal and the proximity to ideal risk factors are calculated and shown in Table 16. The greater the proximity to the ideal option, the less the negative effect of the factors, and the lower the proximity to the ideal option, the more critical the risk.

The graph of the proximity of risk factors to the ideal option is shown in Figure 1. As can be seen, Factor No. 7 (mismatching product specifications with customer needs and tastes) has the longest distance to the ideal option (the

Table 17 Risk factor ranking

Risk Number	Risk factor	Rank
7	Mismatching product specifications with customer needs and tastes	1
4	The emergence of a new rival	2
6	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	3
11	Unbalanced product pricing	4
5	Market volatility	5
1	Lack of access to raw materials	6
3	Lack of liquidity	7
8	Initial false tension of the product on the market	8
12	Decay of product during shipment and storage	9
2	Delay in meeting market needs	10
13	Lack of skilled staff	11
14	Disregarding the proper weight and quantity in the initial product packaging	12
10	Incorrect estimation of the need for product production to use modern equipment	13
9	Changing the sales volume in different seasons	14

Table 18 Risk factor ranking and risk reduction strategies (Guide 2001)

Risk Number	Risk factor	Risk Reduction Strategy
1	Mismatching product specifications with customer needs and tastes	Introducing the product to market and review customer's view
		Paying attention to the tastes and needs of customers in different areas
		Paying attention to the needs of different age groups
		Investigation of food basket of different segments of society
		Evaluating customer views regularly and make necessary corrections
2	The emergence of a new rival	High-tech product production
		Constantly check competitors' performance and their new products
		Dedicating 30-40 percent of banking facilities to research and development on new products
		Making permanent distinctions and continuous improvement of products
3	The risk of losing credibility and the company's opportunity for selling by delivering an unfavorable new product to the market	Ensuring high quality of product (taking into account strict criteria for product acceptance)
		Getting feedback from new product
4	Unbalanced product pricing	Activation of the industrial accounting department
		Implementing value engineering techniques
		Multiple meetings of management, accounting, marketing and sales departments to achieve the ideal product price
5	Market volatility	Determining the right time to market the product according to economic conditions
		Forming a market research team with the presence of organization's managers to identify the market with regard to economic and political change
		Seasonal and annual contracts
6	Lack of access to raw material	diversity in suppliers
7	Lack of liquidity	Planning for financing from various sources (banks, investors)
		Allocating part of the company's revenue to new product development
8	Initial false tension of the product on the market	Offering limited product at an early stage to market
9	Decay of product during shipment and storage	Installation of thermal sensors in transport means
		Selection of transportation vehicle according to destination distance
		Ongoing inspection of shipping system by quality control department
10	Delay in meeting market needs	Cooperation with other dairy companies
		Providing a suitable framework for accurate production planning and scheduling
11	Lack of skilled staff	Conducting continuous training courses for staff
		Paying attention to the skills needed in the time of hiring
		Employing experienced staff related to the relevant work unit
12	Disregarding the proper weight and quantity in the initial product packaging	Competitor's performance evaluation
		Investigating and categorize different segments of the consumer product such as fast food, restaurants, shops, etc. and considering the weight and number of products according to their request
13	Incorrect estimation of the need for product production to use modern equipment	Studying and researching on the required equipment according to the latest technologies
14	Change the sales volume in different seasons	Production of products related to other seasons

most critical risk), and Factor No. 9 (changing the sales volume in different seasons) has the least distance to the ideal option.

5 Risk ranking and risk reduction strategies

According to Sect. 4, risks were identified using experts' interviews. Then, the risk factor measurement criteria were identified and weighted using Shannon entropy. The positive and negative ideal values were obtained, and the proximity of each factor to ideal values was calculated. This section shows the risk factor ranking and risk reduction strategies for each factor in Tables 17 and 18.

As can be seen the ' Mismatching product specifications with customer needs and tastes' is the most critical risk and 'The emergence of a new rival' is placed in the second position.

6 Conclusion

Ramak Company is one of the well-known companies in dairy and ice cream productions whose operations are always exposed to risks. Considering the importance and necessity of risk management in the company's projects, this study proposed FMEA and TOPSIS methods (mentioned in Sect. 3. Methodology) to structure and rank these risks using the managers' opinions. The results showed the weight factor (importance) of the risks under analysis. Accordingly, the mismatch between the product specifications with customer needs and tastes was found to have the highest weight, followed by the emergence of a new rival and the risk of losing the company's credibility and opportunity for selling by delivering an unfavorable new product to the market which are in the second and third positions. Based on the results in this study, a couple of recommendations are provided to the officials of Ramak Company and other food companies:

- Managers of the company are recommended to have a plan for facing the risks by continuously recognizing and assessing the company's risks. Without the use of scientific methods, the decisions made by the managers may diverge a lot from reality; more importantly, inappropriate decisions may be costly.

- Experts of the company can make decisions based on a combination of different approaches and methods derived from different sources like; theories and previous studies, documentation, global and national standards, risk management instructions such as PMBOK, and the views of the managers of the company. So, they can help to increase the position of the company and the achieving its purposes.

- The structuring of the risks helps managers analyze the extent to which the risks can affect and be affected on each other and the improvement of one risk can help improve another one. In this way, managers can focus their attention on those risks whose improvement can change the entire model. More importantly, managers can use the risk mitigation strategies offered in this study to improve their model and make more effective decisions.

- There is no probability of changing some of the risks for experts, and some risks have features that managers must pay attention to when making decisions. Therefore, mixed approaches like multi-criteria decision-making allow experts and decision-makers to have a set of tools to improve their decisions.

- COVID-19 pandemic has affected all industries and systems. The advent of COVID-19 pandemic has showed that all industries should prepare for new changes and risks in order to take immediate actions to overcome the difficult situation.

The results showed that methods used in this research were applied properly. So, other companies and researchers can use these methods and results to gain the best outcomes for their work. Risks with a high rank in this research are significant for other companies and their manager if they want to increase their sales and profit.

7 Future work

The data gathered from one company is not enough for generalization and make big decisions for the whole industry. So, more companies can be investigated for better and more reliable results.

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References

Ali H (2006) Studying risk management techniques and Implementing FMEA in Mihantak Company. Yazd University, Yazd, Iran

Amiri M, Foroushan PC, Poorqanad B (2009) Provide a model for risk assessment of project activities using the AHP method. In: Fifth international conference of project management, 23–37

Ammar A, Berman K, Sataporn A (2007) A review of techniques for risk management in projects. Bench-mark Int J 14:22–36

Anish S, Dinesh K, Pradeep K (2009) Multi-factor failure mode critically analysis using TOPSIS. J Indus Eng Int 5(8):1–9

Antonio R, Francisco O, Ramiro C (2017) An intuitionistic method for the selection of a risk management approach to information technology projects. Inf Sci 375:202–218

Atul S, Pankaj A, Rana RS, Rajesh P (2017) Applications of TOPSIS algorithm on various manufacturing processes: a review. Mater Today Proc 4(4):5320–5329

Aven T (2016) Risk assessment and risk management: review of recent advances on their foundation. Eur J Oper Res 253(1):1–13

Barghi B, Sikari SS (2020) Qualitative and quantitative project risk assessment using a hybrid PMBOK model developed under uncertainty conditions, Heliyon, 6(1)

Baynal K, Sari T, Akpinar B (2018) Risk management in automotive manufacturing process based on FMEA and grey relational analysis: a case study. Adv Prod Eng Manag 13(1):69–80

Behnam V, Salimi M, Charkhchian M (2015) A new FMEA method by integrating fuzzy belief structure and TOPSIS to improve risk evaluation process. Int J Adv Manuf Technol 77(1–4):357–368

Behrouz D, Ehsan H (2010) Determining the best responding strategy to project risk using ANP technique (case study: North Azadegan oil field development project). Indus Manag 2(4):75–92

Berman K, Gunter A, Zhou M, Amornsawadwatana S (2007) A risk mitigation Methodology for new product and process design in concurrent engineering projects. Annal CIRP 56(1):167–170

Boehm BW (1991) Software risk management: principles and practices. IEEE Softw 8(1):32–41

Buyukozkan F (2006) Evaluation of new product development projects using artificial intelligence and fuzzy logic. International conference on knowledge mining and computer science Prague Czeck Republic 11:183–189

Certa A, Enea M, Galante GM, Izquierdo J, La Fata CM (2018) Food safety risk analysis from the producer's perspective: prioritization of production process stages by HACCP and TOPSIS. Int J Manag Decis Mak 17(4):396–414

Chan W (2011) A new approach for selecting portfolio of new product development (NPD) projects. Expert Syst Appl 38:429–434

Chang K, Chang Y, Lee Y (2014) Integrating TOPSIS and DEMATEL methods to rank the risk of failure of FMEA. Int J Inf Technol Decis Mak 13:1229

Chang Tai-Wu, Lo Huai-Wei, Chen Kai-Ying, Liou James J. H (2019) A novel FMEA model based on rough BWM and rough TOPSIS-AL for risk assessment. Mathematics 7(10):874

Chapman C, Ward S (2003) Project risk management: processes, techniques and insights, John Wiley and sons 2

Chauhan AS, Yadav OP, Rathore APS, Soni G (2017) Analysis of risk sources in new product development process using fuzzy failure mode analysis. In: IEEE international conference on industrial engineering and engineering management, 1198–1202

Goodwin SA (2009) The concept and measurement of perceived risk: a marketing application in the context of the new product development process, ASBBS annual conference: Las Vegas 16(1)

Guide A (2001) Project management body of knowledge (PMBOK R GUIDE), Project Management Institute

Gulcin B, Orhan F (2009) A fuzzy-logic-based decision-making approach for new product development. Int J Prod Econ 90:27–45

Gulcin B, Orhan F (2006) Evaluation of new product development projects using artificial intelligence and fuzzy logic. International conference on knowledge mining and computer science Prague Czeck Republic 11:183–189

Hamidreza F, Navvabi HK (2009) Identifying and ranking the strategic risks of investment companies (case study: Ghadir Investment Company). Andishe Modiriat, third year 2:167–197

Honhyi S, Wing WC (2005) Critical success factors for new product development in the Hong Kong toy industry. Technovation 25:293–303

Hossein S, Zahra F, Setareh M (2014) Identifying and evaluating enterprise architecture risks using FMEA and fuzzy VIKOR. J Intell Manuf 27(2):475–486

Hwang CL, Yoon K (1981) Multiple attributes decision making methods and applications. Springer, Berlin

Industry Biography Vizhenameh (2016) Industry news, p 3

Iranian Business development organization report (2016) p 15

Itzhak B-D, Gad R, Raz T (2002) Economic optimization of project risk management efforts, The Israel Institute of Business Research

Jiho Y, Hakan Y, Srinivas T (2016) Risk management strategies in transportation capacity decisions: an analytical approach. J Bus Logist 37(4):364–381

Jutie W, Lin Y-L (2009) An overlapping process modeling to assess schedule risk for new Product development. Comput Ind Eng 57:460–474

Kayis A, Amornsawadwatana Z (2007) A risk mitigation methodology for new-product and process design in concurrent engineering projects. AnnalCIRP 56(1):167

Kirkire MS, Rane SB, Jadhav JR (2015) Risk management in medical product development process using traditional FMEA and fuzzy linguistic approach: a case study. J Indus Eng Int 11(4):595–611

Kotler P, Armstrong G (2010) Translator: Mehdi Zare, Princ Mark 125–127

Kuei-Hu C, Yung-Chia C, Yu-Tsai L (2014) Integrating TOPSIS and DEMATEL methods to rank the risk of failure of FMEA. Int J Inf Technol Decis Mak 13(06):1229–1257

Kumar A et al (2021) Mitigate risks in perishable food supply chains: learning from COVID-19, Technol Forecast Soc Change 166

Lee E, Yongtae P, Jong SG (2009) Large engineering project risk management using a Bayesian belief network. Expert Syst Appl 36:5880–5887

Li G-F, Yi Li C, Chen J, He T, Hou JC (2019) Advanced FMEA method based on interval 2-tuple linguistic variables and TOPSIS. Qual Eng 32:356

Lo HW, Hsu CC, Huang CN, Liou' JJ (2021) An ITARA-TOPSIS based integrated assessment model to identify potential product and system risks' mathematics 9(3):239

Mangelia M, Shahraki A, Hosseinzadeh Saljooghi F (2019) Improvement of risk assessment in the FMEA using nonlinear model, revised fuzzy TOPSIS, and support vector machine. Int J Ind Ergon 69:209–216

Mansoor M (2017) New topics in operation research, Tehran University Publication

Marle Franck (2002) Modèles d'information et méthodes pour aider à la prise de décision en management de projets (Doctoral dissertation, Ecole Centrale Paris)

Mihalis G, Thanos P (2016) Supply chain sustainability: a risk management approach. Int J Prod Econ 171:455–470

Mohammad H, Abbas K, Akbar A, Hossein S, Alireza Y (2017) New approach in identifying and evaluating quality risks in the pharmaceutical industry. J Pharmacoeconomics Pharm Manag 3(1–2):17–20

Moreira AC, Ferreira LMD, Silva P (2020) A case study on FMEA-based improvement for managing new product development risk. Int J Qual Reliab Manag

Nakat Z et al (2021) COVID-19 and the food industry: readiness assessment, Food Control 121

Nik ER, Zegordi SH, Nazari A (2012) Multi-objective optimization model and fuzzy prioritization approach for project risk responses selection (case study: combined cycle power plant of abadan). Knowl Technol 5:1–36

Ping-kit L, Kwai-Sang C (2005) Identifying and prioritizing critical success factors for conflict management in collaborative new product development. Ind Mark Manag 34:761–772

Prisana S, Speece MW (2010) Assessing new product development success factors in the Thai food industry. Br Food J 112:4

Rabei A, Aliakbari S, Mahmoodkhani Z (2011) Ranking new product development challenges in knowledge-based companies. In: second national conference of research and technology management, Tehran, Iran

Richard E (1994) Fairley, risk management for software projects. IEEE Softw 11(3):57–67

Sabzevari M, Sajadi SM, Hadji MM (2020) Supply chain reconfiguration for new product development through risk management approach. SciIran 27(4):2108–2126

Sajid Z (2021) A dynamic risk assessment model to assess the impact of the coronavirus on the sustainability of the biomass supply-chain, Renew Sustain Energy Rev 151

Salimi ZSQ, Roxana F (2014) Study the relationship between risk management and new product development in Iran automobile industry with confirmatory factor analysis and structural equation model. National conference on researches of Industrial Engineering, Hamadan, Iran

Sardar A, Mohammadi IA, Parkhideh MS, Mirzaei F (2009) Evaluation of hazard of crude oil transmission, storage and loading processes at Kharg Oil terminal using FME and CA method. In: Third national conference of safety engineering and HSE management, Sharif University, Tehran, Iran

Selim H, Yunusoglu M, Balaman Ş (2016) A dynamic maintenance planning framework based on fuzzy TOPSIS and FMEA: application in an International Food Company. Qual Reliab Eng Int 32:795–804

Şenel M, Şenel B, Havle C, (2018) Risk analysis of ports in Maritime Industry in Turkey using FMEA based dntuitionistic Fuzzy TOPSIS approach. In: ITM Web of Conferences, p 22

Shahrabi M, Zaeri P (2007) Project selection by using fuzzy (AHP) and TOPSIS technique. Int J Hum Soc Sci 1(3):135–140

Shirani M, Demichela M (2015) Integration of FMEA and human factor in the food chain risk assessment. Int J Soc Behav Edu Econ Bus Indus Eng 9(12)

Soheil M, Jamal S, Mahmood P, Mehran Z (2007) Project selection by using fuzzy (AHP) and TOPSIS technique. Int J Hum Soc Sci 1(3):135–140

Stefan K, Vladimira S, Jozef M (2017) Using the Saaty method and the FMEA method for evaluation of constraints in Logistics Chain. Procedia Eng 187:749–755

Stephen J, Carson TW, Moore WL (2012) Managing the trade-off between ambiguity and volatility in new product development. Innov Manag 29:1061–1081

Taraneh S, Paradi J, Suld C (2005) Information systems project prioritization using data envelopment analysis. Math Comput Model 41:1279–1298

Tay KM, Lim CP (2006) Fuzzy FMEA with a guided rules reduction system for prioritization of failures. Int J Qual Reliab Manag 23(8):1047–1066

The world of Economic (2014) Ramak background, archived from the Original, Wikipedia.org/wiki/$Ramakwebsite - note - 3$

Toljaga-Nikolić D, Todorović M, Bjelica D (2018) Application of the FMEA technique in a project risk analysis. Eur Proj Manag J 8(2):36

Wahyudin NE, Santoso I (2016) Modelling of risk management for product development of yogurt drink using house of risk (HOR) method. The Asia J Technol Manag 9(2):98–108

Wenyan S, Xinguo M, Zhitao X (2013) Risk evaluation of customer integration in new product development under uncertainty. Comput Indus Eng 65:402–412

Zandi P, Rahmani M, Khanian M, Mosavi A (2020) Agricultural risk management using fuzzy TOPSIS analytical hierarchy process (AHP) and failure mode and ffects analysis (FMEA). Agriculture 10(11):504

Zhang Z (2005) A grey evaluation model of inherent risk in product development. Res Dev Manag 17(1):37–42