Journal of Money and Economy
Vol. 10, No.3 Summer 2015

New Product Development Risk Assessment in the Core Banking Using FMEA Combined with COPRAS Method and Grey Relations

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Received: 9/7/2015 Approved: 4/20/2016

Abstract

The present study tries to investigate the existing risks in the new product development process in the core banking field. Due to its use after production, new product development with the fewest errors and risks is always the subject of discussion and investigation among the researchers of this field. This study aims to investigate the most important risks existing in the new product development. The most important issue in this regard is that the market of manufactured products is increasingly competitive and the life-cycle of products is in decline due to environmental impacts. These factors force companies to follow such a process (new product development). Many techniques have been invented and applied in order to assess and manage the existing risks in different processes. Failure modes analysis technique and its resulted effects (FMEA) are considered as one of the most effective techniques that have been used for risk assessment of new product development in this study. Also, CORPAS-G method is used for prioritizing the detected risks. The purpose of this study is to identify the risks of new product and their priority for corrective measures to reduce the probable risks.

Keywords: *Risk assessment, Risk management, New product development, Core banking, FMEA, COPRAS-G*

GEL Classification*: D24, D40, D61, D81, D92*

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1. Introduction

A decrease in revenues gained from selling products forces manufacturing companies to manufacture new products in order to boost sales, increase revenues and eventually gain more market share so that they can partly realize their own short term and long term goals. Also new product manufacturing has a series of risks and errors itself. This study tries to find these errors and prioritize them for corrective measures. In addition, it is less expensive to find and fix defects before using any product.

In today's dynamic world of business, companies are seeking competitive advantage to continuously ensure their survival. There is no doubt that new product development is an introduction for entering this stage. Due to shorter product life cycles and changing customer needs, there is a lot of pressure to reduce the cost and time of new product development. Although new products create new opportunities for companies, the significant risk of these products must not be ignored. There is plenty of information about products in the past and many risks associated with products have been collected in the previous product development projects, however, there are also new and complex situations for product development teams that are associated with many uncertainties. In such a complex situation, official and systematic risk management is necessary in order to achieve certain objectives. However, a small number of product development projects implement risk management processes properly.

Chin et al. (2009) found that in many organizations risk management is often done by informal and non-systematic routines in new product development projects and is largely based on emotions and management perception. As a result, the existence of a systematic approach is essential to identify, analyze and control product development risks. One of these common tools is defect analysis and the effects of failure (FMEA) which is one of the most important detecting techniques and error analysis. This technique is basically a quality analysis assessment of systems or sub-systems for detecting the probable defects of its all elements and tries to assess the effects of the probable defects of their elements and tries to assess the effects of the probable defects on the other parts. This technique is widely used in the manufacturing industries and is an analytic technique which employs technology and knowledge of individuals about detecting predictable errors of a product, process and/or system. However, this technique has its weaknesses and shortcomings as well. For this reason, in recent years, researchers have been trying to fix its flaws in several studies. For example, the relative importance of the severity of the event, the probability of occurrence and the probability of detecting are not considered in the traditional FMEA. It is assumed that they have equal weights, but it is not so in the real world and practical decisions. This situation could lead to a case that the different collections of the severity, the probability of occurrence and the probability of detecting represent the same RNP[1] values. The mathematical formula for the calculation of RPN is also questionable and it is sensitive to small changes of each of triple risk factors (detecting, severity and occurrence). Consequently, it seems that their multiplication for the purpose of obtaining the priority of different risks is not so logical.

Triple risk factors are not measurable and fully detailed; as a result, using certain numbers could not reveal the uncertainty and ambiguity of decision making. Therefore, COPRAS will be used to overcome the shortcomings of RPN calculation method and also Grey criteria and eliminate the uncertainty of risk parameters. Grey criteria are one of mathematical concepts that are widely used in multi criteria decision making. It is a very effective method to deal with problems associated with uncertainty accompanying incomplete and unknown information. Commonly, the information associated with the preferences of decision makers about criteria is expressed according to their qualitative judgment for different reasons. The judgment of decision makers is uncertain in practice as well and it is not expressible by quantitative values. This theory is one of the methods used for studying uncertainty and incompleteness of information. Its use in the mathematical analysis of systems with incomplete information has a growing trend. The advantage of COPRAS method over the other methods of decision making is that the effects of both maximizing and minimizing criteria of the problem are investigated simultaneously.

The main objective of this paper is to identify and rank the risks associated with the product development in the core banking system. Also, detecting the main causes and effects of each risk, developing solutions and recommendations for the detection, prevention and reduction of errors in product development and eliminating defects to achieve high quality products that have the lowest risk for customer are the other objectives of this study.

Using Grey theory in introducing risk analysis of new products in the field of core banking is one of the new aspects of this research. Integrating risk

1. Relative Priority Number

assessment model by Grey theory with Grey COPRAS- FMEA is the other new aspect of the study.

2. Literature Review

2.1. Concepts and criteria

2.1.1. Risk management

Risk management is a process that is developed and implemented with the aim of increasing the effects of positive risk (strengths or opportunities) and reduction of negative risks (weaknesses or risks).

Definition of Risk: Risk in the PMBOK[1] standard is defined as an unreliable accident and incident that, if occurred could affect positively and/or negatively the objectives of the project. With respect to this comprehensive definition of risk, it could be understood that there are two types of risk in the projects:

1. Positive Risk: It is also defined as strength or opportunity. With regard to its nature, this risk provides an opportunity for stakeholders of the project.
2. Negative Risk: It is also defined as weakness or risk. If this risk occurs during the project life cycle, then it could cause some difficulties in the process of the project.

Definitions:

- Risk Factor: A factor that determines the effectiveness of risk.
- Risk Event: Any incident or occurrence of risk is called a risk event.
- Reaction of Risk: Reaction that needs to be done in the event of risk.
- Effect of Risk: Change of existing situation and the effect of risk on this situation.
- Utility Loss: Value lost by the stakeholder is called utility loss. In other words, the effect of risk on each stakeholder is called utility loss.
- Exact Estimate: An estimate which is done by the judgment of real professionals through mathematical methods.

1. Project Management Body of Knowledge

- Probable Estimate: An estimate which is used for uncertain conditions. In this method, calculation of the cost in the real world is done on the basis of the probabilities in the domain of output probabilities of a project.
- Domain Estimation: A decision-making method in the uncertain conditions that is determined by defining the lowest and highest values allocated to each element in the case of risk.
- Risk and Uncertainty: Both are used for expressing the existence of risk, but, they are different from each other.
- Terms of risk refers to the case when there is the probability of risk, but this risk and losses could be estimated. Terms of uncertain condition refers to the case when there is not any information available about the quantity and the probability of risk. Uncertainty is the worst case for risk management.

2.1.1.1. Risk management process

According to PMBOK standard, risk management includes the following processes:

- Risk management programming,
- Risk explanation,
- Qualitative analysis of risk,
- Quantitative analysis of risk,
- Response to risk programming, and
- Follow-up process and risk control.

2.1.1.2. Six steps in risk management process

1. The first step is defining the objectives of the risk management that the project is looking for.
2. When the main objectives of risk management are defined, the risk manager must identify the existing risks. Perhaps, identifying the risks is the most difficult task that the risk manager should do. Failure or inability to identify risks means that the risk manager has not any opportunity to deal consciously with these unknown risks.

3. The next important step is assessment of potential damages during the planning period associated with these risks. This assessment includes determining: (A) The probability or chance of damage occurrence, (B) The effect of these damages on the situation in the case of occurrence, (C) The ability of predicting the damages that will occur. The assessment process is very important because of presenting the more sever risks and consequently presenting the risks which need immediate attention.
4. When the risks are identified and assessed, the risk manager should choose the best combination of tools that are applicable in dealing with problems arising from them. Commonly, these tools are: (a) risk avoidance, (b) reduction of the probability of damage occurrence and/or in the case of occurrence, prevention of its extension, (c) potential damage transformation to the other party (insurance companies or companies that are active in the field of accepting risk), (d) keep or tolerate the damage by himself. The risk manager must consider costs and the other aspects of the use of each combination in the choice of the most suitable combination of tools.
5. After decision-making about the selected tools for risk management, the risk manager must execute the made decisions, and
6. The results of made and executed decisions in the above five steps should be monitored for the purpose of assessing their rationality and determining whether variable conditions create different solutions.

2.1.1.3. Assessing risk techniques

Here are some of the most important techniques for the risk assessment.

- Preliminary linear analysis technique,
- Hazard and Operability Study (Hazop),
- Success Diagram Method (SDM),
- Truth Table Method (TTM),
- Markov Process Technique,
- Event Tree,
- Temporary Carlo simulation technique,

- Safety Audit,
- Fault Tree Analysis, and
- Failure Mode and Effects Analysis (FMEA)

2.1.2. Failure mode and effects analysis (FMEA)

Failure mode and effects analysis is a systematic tool on the basis of teamwork that is applied in defining, identifying, assessing, prohibiting, eliminating and/or controlling the mode of causes and the effects of potential errors in a process, system, scheme or service, before the product or service reaches customer. In other words, FMEA is an analytical method in assessing risk. It tries to identify and evaluate the potential risks in the areas where the risks are assessed, and also the associated causes and effects as far as possible. FMEA method is one of experienced and very useful methods for identification, classification, failure analysis and assessment of the risks caused by them. By this method, the failure rate can be traced and prevented from occurring. Therefore, in summary, FMEA includes identification and assessment of potential errors of plan or product (Marshal, 2012). As a tool for access to a better quality of product, FMEA is used in a wide range, so that it has specific standards in the Japanese, American and European manufacturing companies. Very important advantages are reported by industries that use this technique. For example, western manufacturing industries which have been successful in the use of this technique have reported improving quality, lowering costs and reducing time-to-market by 15 to 45%. One of tremendous advantages of quality analysis technique of failure mode and effect analysis in the manufacturing processes is its ability to add the spirit of cooperation among employees and facilitate teamwork.

FMEA is composed of four letters used in the “Failure Mode and Effects Analysis”. In order to clarify the concept of this clause; its words are defined below:

Failure: The root of this word is Fail and according to the Oxford dictionary, its applicable meaning is: Lack of success; an unsuccessful person or thing; the neglect or omission of expected or required action; a lack or deficiency of a desirable quality; the action or state of not functioning; a sudden cessation of power; and the collapse of a business. Also there are various interpretations of this word in the Aryanpur dictionary that include: failing; rejection; thought greedily and lose out. Failure generally means "non-fulfillment of what has already been asked."

Mode: This word means a method according to which something or an action is done. Its other meanings are: tradition; style; method; way; manner; fashion and the case of occurrence.

Effect: The meaning of this word is the change created due to an action; result; consequence; effective work and employing.

Analysis: Analysis is breaking something to its components for identifying or studying the structure for which the common meaning of analysis is used.

2.1.2.1. FMEA objectives

FMEA is a series of systematic actions with the purpose of:

a) Detection and assessment of potential errors that exist in the design of a system, product and process and estimation of the effects resulted from the occurrence of each of the above factors.

b) Identification of actions that could reduce the probability of risks of possible failure and eliminate them.

c) Identification and application of the actions that can reduce the severity and deterioration resulted from the errors as far as possible.

d) Identification and application of the actions that can increase the exploring ability and in other words, the probability of error revealing before the product reaches the customer.

e) Documentation of the design and product manufacturing process meaning that FMEA analyzes the characteristics of the product's design for the purpose of employing product manufacturing process planning in such a manner that the resulted product meets customer needs and expectations.

2.1.2.2. Steps to apply FMEA

The different types of FMEA including product, design and/or process include the following ten steps:

First: Process review period.

Second: Brainstorming creation (collision warning) to determine the potential failure pattern.

Third: Listing the effects of potential failure.

Fourth: Allocation of a severity grade for each effect.

Fifth: Allocation of an occurrence grade for each failure pattern.

Sixth: Allocation of a recovery grade for each potential failure pattern or its effect.

Seventh: Allocation of a risk acceptance priority for each failure pattern.

Eighth: Detection of the priorities of failure pattern for each necessary action.

Ninth: The necessary action for elimination or reduction potential failure patterns possessing high risk.

Tenth: RPN calculation after reduction or elimination of the effects of potential failure patterns.

2.2. Investigating the process

2.2.1. The deterioration amount

How much is the amount of the deterioration? The score of the deterioration is usually 1 to 10. Number 1 indicates the non-seriousness of the error effect from the customer viewpoint and even the error effect is not important for him. On the other hand, number 10 exhibits the worst probable effects and consequences of error for the customer.

The higher number for deterioration describes:

- The probability of the risk of customer safety, and
- Imposing high cost of error on organization which leads to main financial challenges in serious conditions.

In the table of deterioration numbers, the suggested digital values with their mutual deterioration definition are entered. The definitions that are used for the deterioration gradation of error effect should be compatible with the nature of products of an organization.

Table 1. The Scoring Table of Deterioration Samples

Description of the deterioration gradation	**Score**
The effect of error will not be considered by the customer.	1
Customers realize a very negligible effect, but this effect would not lead to the dissatisfaction and abuse of customer.	2
Negligible effect that causes dissatisfaction and abuse of customer, but does not cause the customer to try to fix it.	3
Negligible effect causes dissatisfaction and abuse of customer and the customer tries to fix it.	4
Little effect that causes dissatisfaction and abuse of customer, but the customer does not try to fix it.	5
Little effect that causes dissatisfaction and abuse of customer and the customer tries to fix it.	6
A typical effect that causes malfunction of plan and/or error effect that causes the reduction of the plan value.	7
Important effect of a big error that will not jeopardize customer safety and does not high const.	8
The critical effect that causes customer dissatisfaction, stops working plan, high costs are jeopardizes customer safety.	9
Very dangerous effect that is followed by a serious risk and/or stops completely working plan and/or an error which creates very high costs for the organization.	10

Source: Nannikar, A.A., Raut, D.N., Chanmanwar, R.M., Patil D. B., 2012. FMEA for Manufacturing Assembly process. International Conference on Technology and Banking Management.

2.2.2. Occurrence

One of the questions that is asked in the filling of the FMEA form for determination of “error conditions” is “how often does this error occur?”

The answer to the question of how often this error or the causes of error occur will lead to the filling of the occurrence column in the FMEA table. There are two methods for answering this question:

First: How often the error occurs.

In the first method, since error occurrence is assessed directly, the estimation will be more exact and explicit.

Second: How often the causes of error occur.

In the second method each of traced causes of error occurrence is scored so it may not be an exact estimate of error occurrence directly.

Table 2. Sample Scoring Table of Occurrence

Occurrence description	The rate	Score
Impossible, very unlikely	Less than 0.01	1
Unlikely event	0.011-0.02	2
Event with little chance	0.021-0.6	3
Low number of events	0.61-2	4
Occasionally occurs	0.001-5	5
Usually occurs	5.001-10	6
Often occurs	10.001-15	7
Mostly occurs	15.001-20	8
Very mostly occurs	20.001-25	9
Certainly occurs	More than 25	10

Source: Nannikar, A.A., Raut, D.N., Chanmanwar, R.M., Patil D. B., 2012. FMEA for Manufacturing Assembly process. International Conference on Technology and Banking Management.

2.2.3. Detection probability

How much is the probability of detection of error or its causes? Before starting the discussion of detection probability and its scoring table, it is necessary to investigate the concept and meaning of detection probability deeply. In fact, there are two different definitions for detection and identification probability in FMEA:

How much is the probability of detection of error before reaching a customer?

How much is the probability of detection of error by the customers before making a disaster?

A very important difference is seen in these two definitions that has not been considered in most cases and in many FMEA texts. Understanding the difference in these two definitions is very necessary.

Table 3. Detection Probability Scoring

Detection Probability	Score
Certainly detectable	1
Detectable with a very high probability	2
Detectable with a high probability	3
Usually detected	4
With the possibility of fifty, fifty detected	5
Low chance of detection	6
Little chance to detect	7
Very little chance to detect	8
unlikely chance for detection	9
Unrecognizable	10

Source: Nannikar, A.A., Raut, D.N., Chanmanwar, R.M., Patil D. B., 2012. FMEA for Manufacturing Assembly process. International Conference on Technology and Banking Management.

The first definition is a question that will be asked for the completion of detection probability column. The second definition of detection probability refers to the suggested actions column in the FMEA form. If it is not possible to reduce the error occurrence probability, it is necessary to mention suggested actions for this error and in this case, the possibility of error detection to the customer before raising disaster. Mostly, warning systems (ID) for error detection are installed to prepare ample opportunities for the user to prevent the catastrophic effects. A sample of detection probability scoring table is shown in the scoring table of detection probability. As it is known, by increasing the score, the chance of detection of error or its cause is reduced.

The detection probability scoring table is defined on the basis of existing control methods, the amount of quality level growth and the existing reliability plans in the organization.

2.3. Core banking

To keep their customers in today's competitive world, banks should pay more attention to their customers' needs, ideas and necessities related to banking services. They must know that in banking sector the voice of customer is a voice that the bank policies should be formed on its basis of it. In the meantime, respecting the customers, appropriate interaction with customers, service assurance, polling customers, having mutual relation with customers, checking customer problems and timely investigation of their complaints, awareness of customer satisfaction, enhancing the quality and speed of service delivery, adaption of bank policies to the needs of customers, investigation of the accuracy of services provided to clients and so forth can be a great help in retaining and attracting customers to banks. This will not be fulfilled unless banks pay more attention to their customers.

Evolutions in the contemporary world cause changes in crowd combination, slow growth of the economic systems as well as increased intensity and complexity in the competitive conditions and many industries have faced excess capacity. New marketing approaches push the trades toward paying more attention to customers. This is because in this situation, acquiring new customers seems to be very difficult and businesses ought to compete with each other in a fixed or reducing market to get higher share. In such conditions, nowadays we are witnessing the revolution of focusing on the communication instead of focusing on trade.

Core banking system is a system that presents overall products, banking services, strategic operations and their central integrated and modular managing through access to a common and centralized data base in the form of a software system. Channels thorough which services of the core banking system are offered could be ATMs, bank branches, internet bank, and POS machines and the like. The core banking is a framework that the development is done on its basis and creation of products and electronic-financial services take place in its framework. There is no doubt that the most complete and the newest banking method that completely is developed on the basis of electronic banking is the core banking which prepares the solutions of connection and linking between all banking systems from island state into a centralized and integrated network.

2.3.1. Features of the Core banking system

Among the key features, this system is equipped with:

A. The ability to process high volumes of transactions for example several million transactions per hour;

B. Flexible infrastructure for ever growing upgrades of existing system;

C. Ability to perform real-time processing;

D. High level of flexibility to design new products; and

E. Access to a maximum level of automation through data centralization.

In fact, the main objective of moving towards core banking is the integration of the bank's services and products in the form of core banking framework and all product operations to be placed under one umbrella. Another important objective is converting customers to bank customers instead of branch customers. In addition, eliminating unnecessary trips in city and its great impact on the reduction of traffic and removing cash from daily business transactions are among its other objectives as well.

2.3.2. Strategic advantages of core banking

Items that can be identified as core banking strategic advantages include:

A. Reduction of costs and risk management;
B. providing firm banking services with reliabile and true real-time processing;
C. Increased innovation through the utilization of update technology;
D. Reduction of the time to localize services and new products in order to respond rapidly to market needs;

E. Reduction of total cost of ownership and achieving higher operational efficiency;
F. Existence of 360-grade view of customers;
G. Productivity enhancement;
H. Reduction of the impact of an aging workforce through recruitment and training of human resources and expertise to keep pace with the trend of changing technology; and
I. More focus on operations to fulfill customer orientation.

2.4. Theoretical principles of research model

2.4.1. Mathematical principles of Grey theory

2.4.1.1. Hazy sets

In fact Grey system theory is constructed on the basis of Grey hazy set. Grey hazy set has some specifications including coexistance (the settlement), proof reception, time effectiveness, awareness, (inform) and structure reception. Therefore, it is understood that Grey hazy set is completely different from Cantor classic set and Zadeh fuzzy set, although the Cantor set is one of the main and clarified cases of the Grey hazy set. In fact, fuzzy or classic systems are special cases of Grey system in which the Grey grade is zero. With regard to formulation, the mathematical principles of Grey systems and fuzzy systems are different from each other. In summary, it could be said that Grey hazy sets possess great specifications to deal with dynamic nature systems.

With respect to the above descriptions, it could be said that:

In Classic Sets: $x, y \in A, xRy \rightarrow R = 1, x\bar{R}y \rightarrow R = 0$

In Fuzzy Sets: $x, y \in A: \mu_g(x, y) \in [0,1]$

But the main question is: How much do x and y contain themselves? In other words, how much is their Grey grade? And then, how are the relations between Grey elements and white elements? Uncertainty about the values of various parameters of the system can be stated by intervals, fuzzy sets and/or random variables. In the Grey system theory, given upper and lower bound intervals are used to express the reliability that can emphasize the inherent ambiguity of the issue. In general, it is proved that expressing the values of the parameters of a system by the numbers of an interval is an effective and efficient method to deal with problems related to ineffective observations.

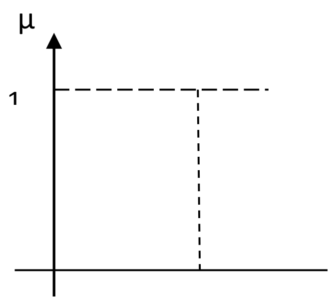
Suppose that X is a world reference set. In this case, a Grey set G of X is defined according to two criteria $\overline{\mu}_G(x), \underline{\mu}_G(x)$.

$$\underline{\mu}_G(x) \;:\; x \;\longmapsto [\,0\,,1\,] \tag{1}$$

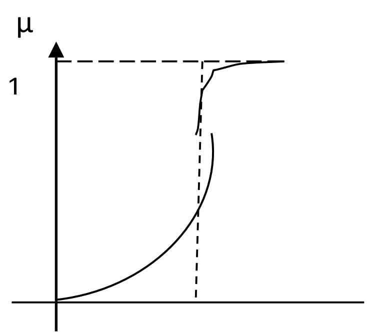
$$\overline{\mu}_G(x) \;:\; x \;\longmapsto [\,0\,,1\,] \tag{2}$$

$\overline{\mu}_G$ and $\underline{\mu}_G$ are the upper and lower membership functions of G respectively. If $\overline{\mu}_G = \underline{\mu}_G$, the Grey set is converted to a fuzzy set. This shows that Grey theory also considers conditions of being fuzzy and can treat fuzzy conditions logically. Figure 1 shows three hazy (Grey), fuzzy and cantor sets.

Figure 1. Hazy (Grey), Fuzzy and Cantor Sets

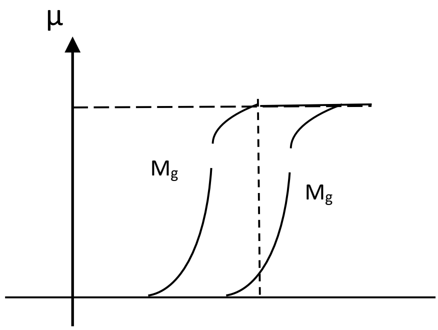


Q_1 = 600 (mm)
Grey Set



Q_2 = 600 (mm)

Fuzzy Set



Q_3 = 600 (mm)
Cantor Set

Source: Deng, J.L., 1989. Introduction to Grey system theory, J. Gray Syst., 1-24.

2.4.1.2. Grey numbers

Each Grey system is described by Grey numbers, Grey equations and Grey matrices in which the Grey numbers are as the atoms and cells of this system. Grey number is defined as a number with unknown value, but the interval that contains its value is known. These numerical intervals contain uncertain data.

Generally and in practice, the Grey number is stated by an interval and/or a set of numbers. Grey numbers are divided into several groups of whivh the most important are:

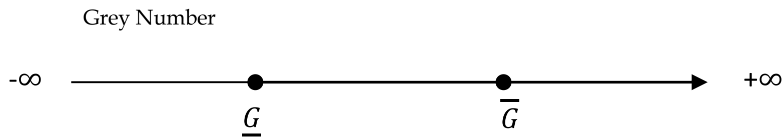
Grey numbers with only low bound are defined as $\otimes G \in [\infty]$ and do not have high bound. In this definition $\underline{G}$ with a fixed value expresses the low bound of the Grey number$\otimes G$. The interval $[\underline{G}, \infty]$ is called the value interval of the Grey number $\otimes G$ and/or briefly a Grey interval. For example the weight of a live tree is a low bound Grey number.

Grey numbers with only high bound are defined as $\otimes G \in [\infty, \overline{G}]$ and do not have low bound. In this definition $\overline{G}$ expresses the high bound of the Grey number$\otimes G$.

A Grey number that has both low bound $\underline{G}$ and high bound $\overline{G}$ is called Grey interval and is shown as$\otimes G \in [\underline{G}, \overline{G}]$.

Figure 2 shows the Grey interval number.

Figure 2. Grey Interval Number

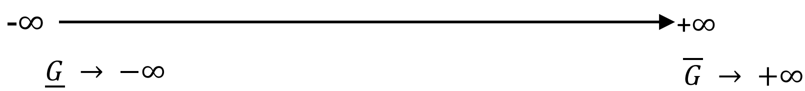


Source: Deng, J.L., 1989. Introduction to Grey system theory, J. Gray Syst., 1-24.

If $\otimes G \in (-\infty, +\infty)$ or $\otimes G \in (\otimes G_1, \otimes G_2)$, means that $\otimes G$ is infinite and its both high and low bounds are Grey numbers, then $\otimes G$ is called a black number.

Figure 3 shows a black number.

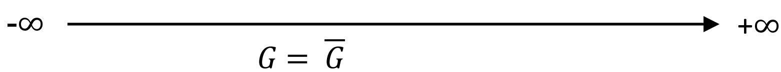
Figure 3. Displaying Black Number



Source: Deng, J.L., 1989. Introduction to Grey system theory, J. Gray Syst., 1-24.

If $(\underline{G}, = \overline{G}), \otimes G \in [\underline{G}, \overline{G}]$, it means that the both high and low bounds $\otimes G$ are equal, then $\otimes G$ is a white number.

Figure 4. Displaying White Numbers



Source: Deng, J.L., 1989. Introduction to Grey system theory, J. Gray Syst., 1-24.

2.4.1.3. Grey operators

The most important mathematical operation on the two Grey interval numbers $\otimes G_2 \in [\underline{G_2}, \overline{G_2}], \otimes G_1 \in [\underline{G_1}, \overline{G_1}]$ and the constant number (a) are defined as follows:

$$\otimes G_1 + \otimes G_2 = [\, \underline{G_1} + \underline{G_2}\, , \overline{G_1} + \overline{G_2}\,] \tag{3}$$

$$\otimes G_1 - \otimes G_2 = [\, \underline{G_1} - \underline{G_2}\, , \overline{G_1} - \overline{G_2}\,] \tag{4}$$

$$a \times \otimes G_1 = [\, a \times \underline{G_1}\, , a \times \overline{G_1}\,] \tag{5}$$

$$\otimes G_1 \times \otimes G_2 = \left[\min(\underline{G_1}\,\underline{G_2}\, , \underline{G_1}, \overline{G_2}\, , \overline{G_1}\,\underline{G_2}\, , \overline{G_1}\,\overline{G_2}), \max(\underline{G_1}\,\underline{G_2}\, , \overline{G_1}\,\underline{G_2}\, , \underline{G_1}\,\overline{G_2}\, , \overline{G_1}\,\overline{G_2}\,)\right. \tag{6}$$

$$\otimes G_1 \div \otimes G_2 = [\underline{G}_1, \overline{G_1}\,] \times [\,\frac{1}{\underline{G_2}}\, , \frac{1}{\overline{G_2}}\,] \tag{7}$$

The length of a Grey number $\overline{G}\, , \underline{G}\,]$ is defined as follows:

$$L\,(\otimes G\,) = \overline{G} - \underline{G} \tag{8}$$

For two intervals A = [a_1 , a_2], B = [b_1 , b_2], we have:

$$P\,(\,A < B) = P\,(\,C = A - B < 0\,)$$
$$= \frac{The\ negative\ length\ of\ the\ C\ interval}{The\ length\ of\ C\ interval}$$
$$= \frac{The\ negative\ length\ of\ the\ C\ interval}{(a_2 - a_1) - (b_2 - b_1)}$$

Therefore for two Grey numbers $\otimes G_1 \in [\underline{G_1}, \overline{G_1}], \otimes G_2 \in [\underline{G_2}, \overline{G_2}]$ in which:

$$L_1 = L\,(\otimes G_1\,) = \overline{G_1} - \underline{G_1} \tag{9}$$

$$L_2 = L\,(\otimes G_2\,) = \overline{G_2} - \underline{G_2} \tag{10}$$

$$L^* = L_2 + L_1 \tag{11}$$

The above probability is calculated as follows:

$$P\,(\otimes G_1 \leq \otimes G_2) = \frac{\max\,(0,\ L^* - \max\,(0,\ \overline{G}_1 - \underline{G}_2))}{L^*} \qquad (12)$$

Definition: For two Grey numbers $P\,\{\otimes G_1 \leq \otimes G_2\}, \otimes G_2 \in [\underline{G}_2, \overline{G}_2], \otimes G_1 \in [\underline{G}_1, \overline{G}_1]$ is called the grey probability grade.

It is assumed that there are four correlations between the two Grey numbers $\otimes G_2$, $\otimes G_1$situations.

If $\underline{G}_1 = \underline{G}_2, \overline{G}_1 = \overline{G}_2$ then two Grey numbers are equal, in this case: $\otimes G_1 = \otimes G_2$ and

$$P\,\{\otimes G_1 \leq \otimes G_2\} = 0.5 \qquad (13)$$

If $\underline{G}_2 > \overline{G}_1$ then the Grey number $\otimes G_2$ is greater than the Grey number$\otimes G_1$, it means that: $\otimes G_2 > \otimes G_1$and

$$P\,\{\otimes G_1 \leq \otimes G_2\} = 1 \qquad (14)$$

If $\overline{G}_2 < \underline{G}_1$ then the Grey number $\otimes G_2$ is lower than the Grey number$\otimes G_1$, it means that $\otimes G_2 < \otimes G_1$ and

$$P\,\{\otimes G_1 \leq \otimes G_2\} = 0 \qquad (15)$$

If there is a common part in the two Grey numbers, then if:

$P\,\{\otimes G_1 \leq \otimes G_2\} < 0.5$, then $\otimes G_2$ is lower than $\otimes G_1$ and if $P\,\{\otimes G_1 \leq \otimes G_2\} > 0.5$ then $\otimes G_2$ is greater than $\otimes G_1$[12, 13].

2.4.2. Algorithm of COPRAS-G method

Criteria in this method include both Min and Max; it means that both cases are calculated simultaneously. COPRAS method with Grey relations consists of 12 steps which are explained as follows:

Step 1: Select a set of important criteria and describe the choice

Step 2: Develop the decision matrix by using the existing verbal phrases (By professionals)

$$\otimes X = \begin{bmatrix} [\otimes x_{11}] & \cdots & [\otimes x_{1m}] \\ \vdots & & \\ [\otimes x_{n1}] & \cdots & [\otimes x_{nm}] \end{bmatrix} = \begin{bmatrix} [\underline{x}_{11}, \overline{x}_{11}] & \cdots & [\underline{x}_{1m}, \overline{x}_{1m}] \\ \vdots & & \\ [\underline{x}_{n1}, \overline{x}_{n1}] & \cdots & [\underline{x}_{nm}, \overline{x}_{nm}] \end{bmatrix}$$

$$i = 1, \dots, m \qquad j = 1, \dots, n \qquad (16)$$

The Grey number $\otimes x_{ij}$ is defined with a low limit as $\underline{x}_{ij}$ and with a high limit as $\overline{x}_{ij}$.

Step 3: Determine the weights of criteria (q_j) by AHP or professionals (In this study, it is done by professions).

Step 4: Normalize the decision matrix $\otimes X$ by the following formulas:

$$\tilde{\underline{x}}_{ij} = \frac{\underline{x}_{ij}}{\frac{1}{2}(\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \overline{x}_{ij})} = \frac{2\ \underline{x}_{ij}}{\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \overline{x}_{ij}} \qquad (17)$$

$$i = \overline{1, m}\ ,\ j = \overline{1, n}$$

$$\tilde{\overline{x}}_{ij} = \frac{\overline{x}_{ij}}{\frac{1}{2}(\sum_{i=1}^{m} \underline{x}_{ij} + \sum_{i=1}^{m} \overline{x}_{ij})} = \frac{2\ \overline{x}_{ij}}{\sum_{i=1}^{m} (\underline{x}_{ij} + \overline{x}_{ij})} \quad \circledast \qquad (18)$$

In this formula ⊛ $\underline{x}_{ij}$ is the least value of the ith choice of jth criteria and $\overline{x}_{ij}$ is the highest value of the ith choice of the jth criteria.

N is the number of criteria and m is the number of comparable choices. Therefore, the normalized matrix $\otimes X$ is in the following form:

$$\otimes \tilde{X} = \begin{bmatrix} [\tilde{\underline{x}}_{11}, \tilde{\overline{x}}_{11}] & \cdots & [\tilde{\underline{x}}_{1m}, \tilde{\overline{x}}_{1m}] \\ \vdots & & \\ [\tilde{\underline{x}}_{n1}, \tilde{\overline{x}}_{n1}] & \cdots & [\tilde{\underline{x}}_{nm}, \tilde{\overline{x}}_{nm}] \end{bmatrix} \qquad (19)$$

Step 5: The calculation of the weight normalized decision matrix $\otimes \hat{X}$ that is in the following form:

$$\otimes \hat{x}_{ij} = \otimes \tilde{x}_{ij} \cdot q_j \quad \text{یا} \quad \begin{cases} \hat{\underline{x}}_{ij} = \tilde{\underline{x}}_{ij} \times q_j \\ \hat{\overline{x}}_{ij} = \tilde{\overline{x}}_{ij} \times q_j \end{cases} \quad \circledast \qquad (20)$$

In the formula ⊛ q_j is the weight of jth criteria.

Then, the normalized decision matrix is:

$$\otimes\hat{x} = \begin{bmatrix} [\otimes\hat{x}_{11}] & \cdots & [\otimes\hat{x}_{1m}] \\ \vdots & & \\ [\otimes\hat{x}_{n1}] & \cdots & [\otimes\hat{x}_{nm}] \end{bmatrix} = \begin{bmatrix} [\underline{\hat{x}}_{11}, \bar{\hat{x}}_{11}] & \cdots & [\underline{\hat{x}}_{1m}, \bar{\hat{x}}_{1m}] \\ \vdots & & \\ [\underline{\hat{x}}_{n1}, \bar{\hat{x}}_{n1}] & \vdots & [\underline{\hat{x}}_{nm}, \bar{\hat{x}}_{nm}] \end{bmatrix} \quad (21)$$

Step 6: Calculate the total of p_i (for the criteria of maximizing type) that p_i is preferred (k is the number of Maximizing criteria).

$$p_i = \frac{1}{2} \sum_{j=1}^{k} (\underline{\hat{x}}_{ij} + \bar{\hat{x}}_{ij}) \quad (22)$$

Step 7: Calculate the total of R_j (for the criteria of Minimizing type).

That in this formula (m-k) is the number of criteria which should be minimized.

$$R_i = \frac{1}{2} \sum_{j=k+1}^{k} (\underline{\hat{x}}_{ij} + \bar{\hat{x}}_{ij}) \qquad j = \overline{k, m} \quad (23)$$

Step 8: Determine the minimal amount R_i

$$R_{min} = \min_i R_i \quad ; \quad i = \overline{1, m} \quad (24)$$

Step 9: Calculate the relative importance of each of choices by the following way:

$$Q_i = P_i + \frac{\sum_{i=1}^{m} R_i}{R_i \sum_{i=1}^{m} \frac{1}{R_i}} \quad (25)$$

Step 10: Determine the optimized criteria kk = max $_i Q_i$ $i = \overline{1, m}$

$$k = \max_i Q_i \qquad i = \overline{1, m} \quad (26)$$

Step 11: Determine the priority of choices

Step 12: Calculate grade value of each choice

$$N_i = \frac{Q_i}{Q_{max}} \times 100\ \% \quad (27)$$

That Q_i, Q_{max} are the weight amount of choices derived from formula 25.

Zavadskas et al., demonstrated a case study for the selection of contractor on the basis of multiple attributes of efficiency with fuzzy inputs applying COPRAS-G method. Podvezko compared SAW (Simple Additive Weighting) method and COPRAS method for multi criteria evaluation models. The COPRAS method outperform by eliminating the drawbacks of the SAW method. Saaty introduced AHP technique to solve complex problems using multiple criteria.

Pitchipoo et al. (2014) proposed COPRAS based MCDM approach to reduce the area of blind spots in the sides and rear side of the heavy vehicle using the design parameters of rear view mirror.

Recent applications of COPRAS-G are, bank evaluation [Ginevicius & Podvezko, (2008)], employee selection [(Datta et al. (2009); Zolfani et al.(2012a)], website evaluation [Bindu Madhuri et al., (2010)], material selection for engineering applications [Chatterjee et al. (2011)], building renovation and construction [Bitarafan at al., (2012); Medineckiene & Björk, (2011)], location planning [Rezaeiniya et al. (2012); Zolfani, et al. (2011)], university evaluation [Das et al. (2012)], container terminal technology assessment [Barysiene, (2012)], supplier evaluation and selection [Sahu et al. (2012); Zolfani at al. (2012b)], and market segment evaluation and selection [Aghdaie et al. (2013)].

3. Research Methodology

Regarding the objective, the present study is an applied research. In this study, the researcher is trying to assess and rank the key factors in the new product development in core banking. The result of this study can be used to improve the recognition of the important effective factors in this process, deciding and establishing a consensus among the managers of company. Since many of complexities of the existing process were not understandable by the use of questionnaire in this research, quality methods and interview with the associated professionals are used. On the other hand, for the purpose of weighing criteria, risk assessment was done by using a few data. Consequently, questionnaire and also real documentations are used. Data collection methods were library studying, questionnaire, interview and observation. At first, for recognizing new product development in the software and dominance on it, library studies including documents, books, magazines and authentic Iranian and foreign sites were carried out. After that, by the use of interview with professionals and managers and questionnaire tool, the associated risk is detected and verified. Then, the associated risks were documented. Finally, to extract profession's opinions about the relation between triple factors of risks (severity, occurence probability and detection) and their relative importance the questionnaire tool was used and the triple factors associated with the verified risks were surveyed. Also, ten steps of FMEA and COPRAS-G were used for prioritization.

4. Research Findings

4.1. Priority of risks by using three criteria

COPRAS-G method is used for final priority of risks. The theory of this method was explained in the previous sections. The calculation phase of this method is coded in the MATLAB software environment, so that it is possible to read the numbers from EXCEL software environment. Also the result will be transferred to the (EXPORT) software. The written code is given in the appendix.

The first step of applying COPRAS-G is determination of input data to model in the form of the upper and lower limits of measurement criteria. Table 4 shows the summary of results of indicators. The numbers of this table is the mean of numbers which are collected by the questionnaire.

Table 4: Results of the Questionnaire of Criteria Measurement for the Identified Risks

Risk factor	The severity of the consequences of the event		Probability of the event		Likelihood of event detection	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
1. The lack of access to technology for system construction	4.1	9.3	4.4	8.7	4.7	8.2
2. The scope of the project is ill-defined	5.5	9.4	4.7	7.7	3.4	6.5
3. The requirements of a stakeholder is not identified	3.9	9.2	5.2	8.8	4.9	8.6
4. A stakeholder is completely missing	3.3	8.3	4.8	9.5	4.5	9.3

Risk factor	The severity of the consequences of the event		Probability of the event		Likelihood of event detection	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
5. The number and skills of programmers are not enough	4.8	9.3	5.5	9.8	6.4	9.5
6. system fails under high load	5.2	9.6	4.4	8.6	6.3	8.9
7. The system components are not integrated into a single architecture	3.6	7.9	3.8	7.8	3.5	7.3
8. High cost of future developments of the system	3.9	7.9	3.6	8.0	2.9	7.9
9. The system does not produce the required quality	7.0	9.9	4.8	8.2	4.4	7.6
10. users do not have the ability to work with system	2.4	6.9	4.3	9.8	2.9	7.9
11. Unable to buy the necessary software licensing	2.2	7.6	4.2	9.0	2.4	9.3
12. significant deviation from the initial planning	4.2	8.3	6.4	9.3	3.7	7.7
13. The system is experiencing security problems	7.8	10.2	6.4	8.3	4.9	6.9
14. changes in the needs of stakeholders is much more	6.1	9.5	6.6	9.9	4.8	8.6

Source: Authors’ calculations.

The next step is determination of the relative weight of criteria. On the basis of conclusion and the average of experts’ opinions, the weights of criteria are calculated in table below:

Table 5. The Relative Weights of FMEA Criteria

Likelihood of occurrence detection	Event probability	Severity of occurrence consequences
0.45	0.35	0.20

Source: Authors' calculations.

After employing COPRAS-G method, in the next step, matrix of criteria measurement with their relative weights are normalized and standardized. The results are given in the following table:

Table 6. The Results of Normalizing the Measured Criteria for Risks

Risk factor	The severity of the consequences of the event		Probability of the event		Likelihood of the event detection	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
1. The lack of access to technology for system construction	0.020	0.045	0.016	0.032	0.011	0.019
2. The scope of the project is ill-defined	0.027	0.045	0.017	0.028	0.008	0.015
3. The requirements of a stakeholder is not identified	0.019	0.044	0.019	0.032	0.011	0.020
4. A stakeholder is completely missing	0.016	0.040	0.017	0.035	0.010	0.021
5. The number and skills of programmers are not enough	0.023	0.045	0.020	0.036	0.015	0.022
6. System fails under high load	0.025	0.046	0.016	0.031	0.014	0.021
7. The system components are not integrated into a single architecture	0.017	0.038	0.014	0.029	0.008	0.017
8. High cost of future developments of the system	0.019	0.038	0.013	0.029	0.007	0.018
9. The system does not produce the required quality	0.034	0.048	0.018	0.030	0.010	0.018
10. Users do not have the ability to work with system	0.012	0.033	0.016	0.036	0.007	0.018
11. Unable to buy the necessary software licensing	0.011	0.036	0.015	0.033	0.005	0.021
12. Significant deviation from the initial planning	0.020	0.040	0.023	0.034	0.009	0.018
13. The system is experiencing security problems	0.037	0.049	0.023	0.030	0.011	0.016
14. Changes in the needs of stakeholders is much more	0.029	0.046	0.024	0.036	0.011	0.020

Source: Authors' calculations.

Finally, the results of calculation of ranking and priority of risks are presented in the following table:

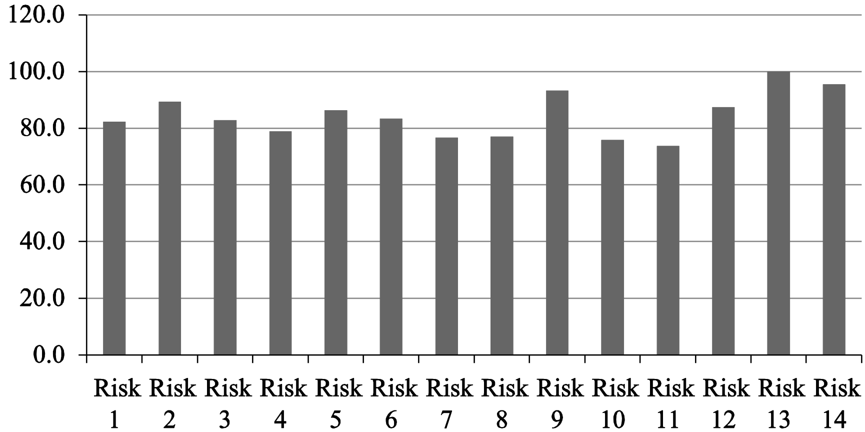
Table 7. The Results of Calculation of Ranking and Priority of Risks

Risk factor	Calculation			Final Rank	
	P_j	R_j	Q_j	N_j	Rank
1. The lack of access to technology for system construction	0.06	0.01	0.07	82.3	9
2. The scope of the project is ill-defined	0.06	0.01	0.08	89.7	4
3. The requirements of a stakeholder is not identified	0.06	0.02	0.07	82.8	8
4. A stakeholder is completely missing	0.05	0.02	0.07	78.8	10
5. The number and skills of programmers are not enough	0.06	0.02	0.07	86.0	6
6. System fails under high load	0.06	0.02	0.07	83.3	7
7. The system components are not integrated into a single architecture	0.05	0.01	0.07	77.1	12
8. High cost of future developments of the system	0.05	0.01	0.07	77.4	11
9. The system does not produce the required quality	0.06	0.01	0.08	93.4	3
10. Users do not have the ability to work with system	0.05	0.01	0.06	76.0	13
11. Unable to buy the necessary software licensing	0.05	0.01	0.06	73.9	14
12. Significant deviation from the initial planning	0.06	0.01	0.07	87.5	5
13. The system is experiencing security problems	0.07	0.01	0.08	100.0	1
14. changes in the needs of stakeholders is much more	0.07	0.02	0.08	95.3	2

Source: Authors' calculations.

The calculated final point for each risk is shown in the N_j column. If this point is higher for the risk factor, it indicates that the risk factor is more probable and more severe than others. However, its detection is still less probable. The following diagram compares the calculated final points for risk factors.

Figure 5. The Calculated Final Points for Risk Factors



Source: Authors' calculations.

As it can be seen, the risk factor no. 13 namely "Safety Problems of System" is in the first place. This means that it is the most important factor. In comparison with the others, this factor is more probable, more severe and yet its detection is less probable. Thus, it can be said that the organization is more vulnerable with regard to this factor and it should be more considered more during the software production process. Risk factors ranks of 2, 3 and 4 are respectively: stakeholder needs variations do not exceed the limit, lack of the necessary quality of produced system and the range of project is not defined precisely.

4.2. Sensitivity Analysis Results

In this section, sensitivity analysis results of ranking and priority of risks with respect to variations that may be created in the relative weights of criteria will be applied (table 8). The current weights for FMEA criteria are derived by surveys of experts and the results verification and their reproducibility are examined. In spite of this, there may be small changes in the amount of these weights in reality. It is essential to note that applying sensitivity analysis is somehow considered as uncertainty analysis in the modeling environment.

Table 8. The Relative Weights of FMEA Criteria in Different Scenarios of Sensitivity Analysis

Scenario	The severity of the event consequences	Occurrence probability	Likelihood of occurrence detection
Base	0.2	0.35	0.45
Scenario 1	0.2	0.4	0.4
Scenario 2	0.1	0.45	0.45
Scenario 3	0.4	0.3	0.3
Scenario 4	0.2	0.6	0.2
Scenario 5	0.2	0.2	0.6

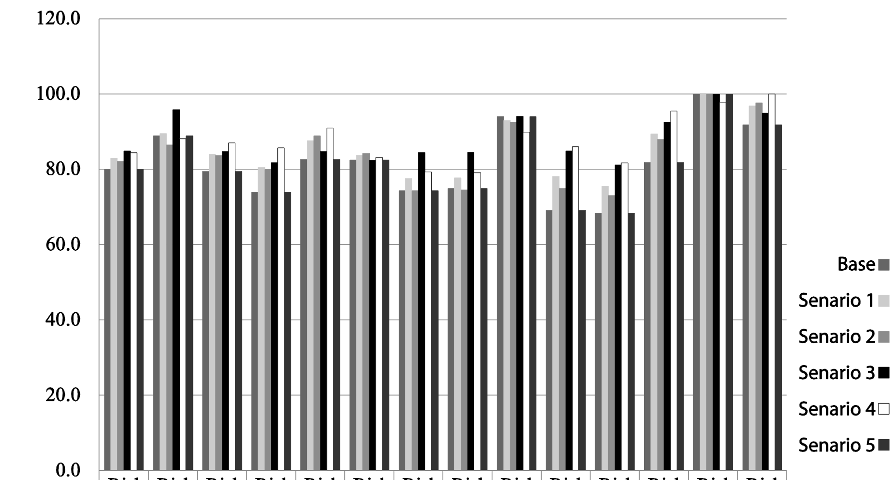
Source: Authors' calculations.

Scenarios 1 to 5 are designed with a specific goal. In Scenario 1, there is a very small change in intensity and probability weights and the weight of detection probability is fixed. In Scenario 2, the weight of detection probability is very low and the remainder weights are divided equally between the severity and probability. This Scenario considers the organization which does not care about detection probability. Although, this lack of care is not due to lack of inherent importance of detection probability, the policy of such an organization says that if even one misadventure about software is detected, then, it is not possible to compensate and/or the organization does not want to focus on failures detection, rather, prevention of their occurrence is more important.

In the Scenario 3, there is an opposite view with regard to Scenario 2, so that a significant weight is considered for failure detection probability. In scenario 4, significant importance is considered for the failure occurrence probability and it indicates the policy that this organization does not ever want any failure to occur in the system. Therefore, the priorities of those risks which are more probable are more. On the other hand, in the Scenario 5 the more significance is considered for the severity of the consequences of failure and this indicates that in this scenario organization believes that compensation for damages is very difficult and in some cases impossible. Therefore, risks that have higher severity of the consequences of failure are given greater priority to prohibit serious damages with a high cost.

In the above scenarios, the results of employment of COPRAS-G method are presented in the Diagram 2. As it can be seen, the priority of risk factors changes in different scenarios are shown. For example risk factor 2, namely "The domain of project is not defined precisely" in Scenario 3 allocates high priority to itself. Scenario 3 is a scenario in which has considered with a very high importance for the occurrence detection probability and this is while the probability of detection of risk factor 2 is low. Similar changes are occurred for risk factors No. 7, 8, 10 and 11. Meanwhile, a common priority can be considered for different scenarios in which the risk factors No. 13, 14 and to some extent risks No. 9 and 10 are placed in the relative priorities.

Figure 6. **The Results of Sensitivity Analysis**



	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5	Risk 6	Risk 7	Risk 8	Risk 9	Risk 10	Risk 11	Risk 12	Risk 13	Risk 14
Base ■	80.0	88.9	79.5	74.0	82.6	82.5	74.3	74.9	94.0	69.1	68.3	81.8	100.0	91.8
Senario 1 ■	83.0	89.4	84.0	80.5	87.6	83.7	77.5	77.7	93.0	78.1	75.6	89.4	100.0	96.8
Senario 2 ■	82.1	86.5	83.7	79.9	88.9	84.3	74.3	74.6	92.5	74.9	73.0	87.9	100.0	97.7
Senario 3 ■	84.9	95.8	84.8	81.7	84.7	82.4	84.5	84.5	94.1	84.9	81.1	92.5	100.0	95.0
Senario 4 □	84.4	88.0	87.0	85.7	90.9	83.1	79.3	79.1	89.9	86.0	81.7	95.5	97.8	100.0
Senario 5 ■	80.0	88.9	79.5	74.0	82.6	82.5	74.3	74.9	94.0	69.1	68.3	81.8	100.0	91.8

Source: Authors' calculations.

5. Discussion and Conclusion

This study aimed at evaluation of the risk in software development projects. The tool used was failure mode and effects analysis (FMEA) which is one of the most important techniques to identify and analyze the errors. This technique is basically a qualitative analysis that investigates systems or sub systems to detect the probable defects of its overall components and tries to assess the effects of probable defects on the remaining sections of system. The relative importance of event severity, probability of occurrence and likelihood of detection cannot be considered by traditional techniques and they were assumed to have the same weight, but this is not the case in the real world and practical decisions. This can lead to errors in the risk assessment. Furthermore, three risk factors in the FMEA are often not quite accurately measurable. Therefore, using the fixed numbers could not show the uncertainty and ambiguity of decision making. COPRAS technique is used in this research to overcome the weakness of the calculation method of RPN, and the Grey theory is used for overcoming the certainty of risk parameters. The results showed that the risk factor (13), the "security problems of system" has the first place in the sense that it is the most important risk factor. In comparison to others, this factor is more probable, more severe and yet its detection is less probable. Thus, it can be said that the organization is more vulnerable with regard to this factor and it should be considered more during software production process. Ranks of 2, 3 and 4 are risk factors respectively: Stakeholder needs variations do not exceed its limit, lack of the necessary quality of produced system and the range of project is not defined precisely.

The sensitivity analysis of results of ranking and prioritizing risks due to changes that may occur in the relative weights of the criteria was performed in the form of 5 scenarios. Scenarios 1 to 5 are designed with a specific goal. In Scenario 1, there is a very small change in intensity and probability weights and the weight of detection probability is fixed. In Scenario 2, the weight of detection probability is very low and the remainder weights are divided equally between the severity and probability. This scenario considers the organization which does not care about detection probability. The lack of care is not due to the lack of inherent importance of detection probability, but the policy of such an organization says that if even one misadventure about software is detected, it is not possible to compensate and/or the organization does not want to focus on failures detection, rather, the prohibition of their occurrence is very more important. In the scenario 3, there is opposite view with regard to scenario 2, so that a significant weight is considered for failure detection probability. In scenario 4, significant importance is considered for the failure occurrence probability and it indicates the policy that this organization does not ever want that any failure occurring in the system. Therefore, those risks which are more likely to uccur are given higher priorities. On the other hand, in the scenario 5 the more significance is considered for the severity of the consequences of failure and this indicates that organization considers the compensation of damages very difficult and in some cases impossible. Therefore, risks that have higher severity of the consequences of failure are given greater priority to prohibit serious damages with a high cost.

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