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Evaluation of Risks in New Product Innovation

Emre Alptekin, Damla Yalçınyiğit, and Gülfem Alptekin

***Abstract*—**In highly competitive environments, a growing number of companies must regularly launch new products speedily and successfully. A company's success is based on the systematic, conscious product designing method which meets the market requirements and takes risks as well as resources into consideration. Research has found that developing and launching new products are inherently risky endeavors. Hence in this research, we aim at introducing a risk evaluation framework for the new product innovation process. Our framework is based on the fuzzy analytical hierarchy process (FAHP) methodology. We have applied all the stages of the framework on the risk evaluation process of a pharmaceuticals company.

***Keywords*—**Evaluation, risks, product innovation.

I. INTRODUCTION

INNOVATION is fast becoming a crucial factor in company performance and survival as a result of the evolution of the competitive environment. Product innovation is an inherently cross-functional process involving a range of internal and external players. This process needs to be managed from a number of perspectives - product & business strategy, product & project portfolios, individual projects and external relationships. An important aspect of all of these is the management of risk - whether technical, market, commercial or project-related [1]. This element assists innovation managers in reviewing how their own processes deal with these challenges.

Product innovation is not only technical subject but also a series of well coordinated activities in which market, professional and strategic aspects should come across. At the end of the innovation process every company wants to achieve an optimum concerning time, costs and the customers' reaction [2]. It does not matter how different or unique a project is; there is no doubt that every project contains some degree of uncertainty and there is no risk-free project. Experience and some studies show that risk management undertaken in a project has an effect on the level of success of a project [3].

This study mainly focuses on the evaluation phase of the project risk management process, which is a certain common element in all approaches. Risk evaluation is the process of assessing the impact and likelihood of identified risks [4].

Authors are with Galatasaray University, Istanbul, Turkey (e-mails: ealptekin@gsu.edu.tr; dyalcinyigit@gsu.edu.tr; gisiklar@gsu.edu.tr).

The aim of risk evaluation is determining the importance of risks and prioritizing them according to their effects on project objectives for further attention and action [3].

As risks are multidimensional, they should be evaluated with respect to more than one criterion to get more accurate and reliable results. The analytic hierarchy process (AHP) is a decision support tool that can be used to solve complex decision problems taking into account tangible and intangible aspects. Therefore it helps decision-makers to make decisions involving their experience, knowledge and intuition. Because AHP does not take into account the uncertainty associated with the mapping of one's judgment to a number and also the subjective judgments, selection, and preference of decision makers exert a strong influence in the AHP; fuzzy sets theory can be used to overcome these shortcomings of AHP. In this article, we propose the use of fuzzy AHP as a suitable and practical way of evaluating project risks.

The rest of the paper is organized as follows: Section II represents the fuzzy AHP methodology, which is the basis of our evaluation framework. The framework, its elements and its application steps are given on a case study in Section III. After giving the results of the case study in Section IV, we conclude our paper.

II. THE FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

The AHP literature includes several approaches considering the use of fuzzy set theory to incorporate linguistic variables into calculations. In this work, we used the fuzzy AHP process as proposed by Chang [5].

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set, and $G=\{g_1, g_2, \ldots, g_m\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal, g_i, is performed respectively [5-7]. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{g_i}^{1}, M_{g_i}^{2}, \ldots, M_{g_i}^{m}, \qquad i = 1, 2, \ldots, n. \tag{1}$$

where all $M_{g_i}^{j}$ ($j = 1, 2, \ldots, m$) are fuzzy triangular fuzzy numbers (Table I).

The steps of fuzzy AHP can be given as follows:

Step 1. The value of fuzzy synthetic extent with respect to the i^{th} object is defined as,

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \tag{2}$$

TABLE I
LINGUISTIC SCALE AND CORRESPONDING FUZZY NUMBERS

Linguistic scale	Triangular fuzzy number
Very low	(1/5, 1/5, 1/3)
Low	(1/5, 1/3, 1)
Just equal	(1, 1, 1)
Slightly high	(1/3, 1, 3)
High	(1, 3, 5)
Very high	(3, 5, 5)

To obtain $\sum_{j=i}^{m} M_{g_i}^{j}$ perform the fuzzy addition operation of *m* extent analysis values for a particular matrix such that

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{3}$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}$, perform the fuzzy addition operation $M_{g_i}^{j}$ (j = 1, 2,…, m) values such that,

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{4}$$

and then compute the inverse of the vector in equation (4) such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right)$$

Step 2. The degree of possibility of $M_2 = \left(l_2, m_2, u_2\right) \geq M_1 = \left(l_1, m_1, u_1\right)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x} \left[\min \left(\mu_{M_1}(x), \mu_{M_2}(y) \right) \right] \tag{5}$$

and can be equivalently expressed as,

$$V(M_2 \geq M_1) = hgt\left(M_1 \cap M_2\right) =$$

$$\mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2)(m_1 - l_1)} & \text{otherwise} \end{cases} \tag{6}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}. To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3. The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i = 1, 2,…, k) can be defined by

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \ldots \text{ and } (M \geq M_k)] = \min V(M \geq M_i),\ 1, 2, 3, ..., k \tag{7}$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \tag{8}$$

for k = 1, 2,…, n; $k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \tag{9}$$

where A_i (i = 1, 2,…, n) are n elements.

Step 4. Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{10}$$

where W_i is a nonfuzzy number [6] .

III. EVALUATION FRAMEWORK AND THE APPLICATION

The objective in this research is to evaluate the risks in a new product innovation project. The evaluation process contains two main steps. In the first step, we determine the importance of each risk identified by the company. The second step involves determining the influence of these risks on each phase of new product innovation project. The necessary calculations are performed using fuzzy analytical hierarchy process (FAHP). As the initial step, we establish the hierarchy of the problem. At the top of the hierarchy is the goal, which is the evaluation of risks. The next level involves the risk groups (criteria). Each risk group has its own sub-criteria. The second step of FAHP is the determination the priorities associated with criteria and sub-criteria using pairwise comparisons. The stages of innovation process are defined as the alternatives. Similar to criteria and sub-criteria, the importance of each stage is obtained by doing pairwise comparisons. Thus, we do not only identify the stages with high risks, but also obtain the effect of each risk on each stage of innovation. The hierarchy of the problem is depicted in Fig. 1.

The application of the proposed methodology is carried out in a leading pharmaceuticals company. The main reasons for selecting this company is that; in pharmaceuticals industry, competition is intense, risks are high, large amount of investment is required for research and development activities and the diversity of products is relatively high. The selected company is a global firm with one of the world largest research and development budgets.

The evaluations of criteria and the stages of innovation projects are performed by five experts from purchasing, production, production planning, marketing and finance departments of the company. The reason for using experts from different departments is that each department plays an active role during new product innovation. Moreover, the diversity of experts makes the evaluation process more reliable.

A. Risk Evaluation

1. Evaluation of Risk groups

In this stage, the experts are demanded to compare five principal criteria as given below:

- Organizational risks (A),
- Technical risks (B),
- Financial risks (C),
- Market risks (D),
- Production resources risks (E).

The linguistic evaluations are transformed to fuzzy numbers which are given in Table II.

TABLE II
FUZZY EVALUATION MATRIX FOR RISK GROUPS

	A	B	C	D	E
A	(1,1,1)	(0.2,0.2,0.33)	(0.2,0.33,1)	(0.2,0.2,0.33)	(0.33,1,3)
B	(3,5,5)	(1,1,1)	(0.33,1,3)	(1,1,1)	(1,3,5)
C	(1,3,5)	(0.33,1,3)	(1,1,1)	(0.2,0.33,1)	(0.33,1,3)
D	(3,5,5)	(1,1,1)	(1,3,5)	(1,1,1)	(3,5,5)
E	(0.33,1,3)	(0.2,0.33,1)	0.33,1,3)	(0.2,0.2,0.33)	(1,1,1)

The values in the matrix help us to calculate the synthetic extent values for each criterion. In fact, these values are the priorities of criteria given with fuzzy numbers (Table III).

TABLE III
FUZZY SYNTHETIC EXTENT VALUES OF RISK GROUPS

S_A	S_B	S_c	S_D	S_E
(0.03, 0.07, 0.26)	(0.11, 0.29, 0.68)	(0.05, 0.16, 0.59)	(0.15, 0.39, 0.77)	(0.03, 0.09, 0.38)

Next, we have to make pairwise comparisons of these synthetic extent values to obtain V_i values (Table IV).

TABLE IV
POSSIBILITY OF BEING GREATER

$V(S_A>S_B)$	0.41	$V(S_B>S_E)$	1.43	$V(S_D>S_C)$	1.46
$V(S_A>S_C)$	0.69	$V(S_C>S_A)$	1.20	$V(S_D>S_E)$	1.68
$V(S_A>S_D)$	0.24	$V(S_C>S_B)$	0.80	$V(S_E>S_A)$	1.06
$V(S_A>S_E)$	0.91	$V(S_C>S_D)$	0.66	$V(S_E>S_B)$	0.58
$V(S_B>S_A)$	1.50	$V(S_C>S_E)$	1.15	$V(S_E>S_C)$	0.82
$V(S_B>S_C)$	1.24	$V(S_D>S_A)$	1.76	$V(S_E>S_D)$	0.43
$V(S_B>S_D)$	0.83	$V(S_D>S_B)$	1.19		

The normalized value of final priority weights for each criterion is given in Table V.

TABLE V
NORMALIZED PRIORITIES OF RISK GROUPS

Criterion	**A**	**B**	**C**	**D**	**E**
W	0.07	0.25	0.20	0.35	0.13

From the given results, we can state that the most important risk group in the product innovation process is the market risks with the priority weight of 35%. The market risks group is followed by the technical risks and financial risks with the priority weights of 25% and 20%, respectively.

2. Evaluation of Sub-criteria

We follow the same stages in the evaluation process of sub-criteria. Because of space limitations, we only give the final table summarizing the priority weights of risk groups and sub-criteria (Table VI).

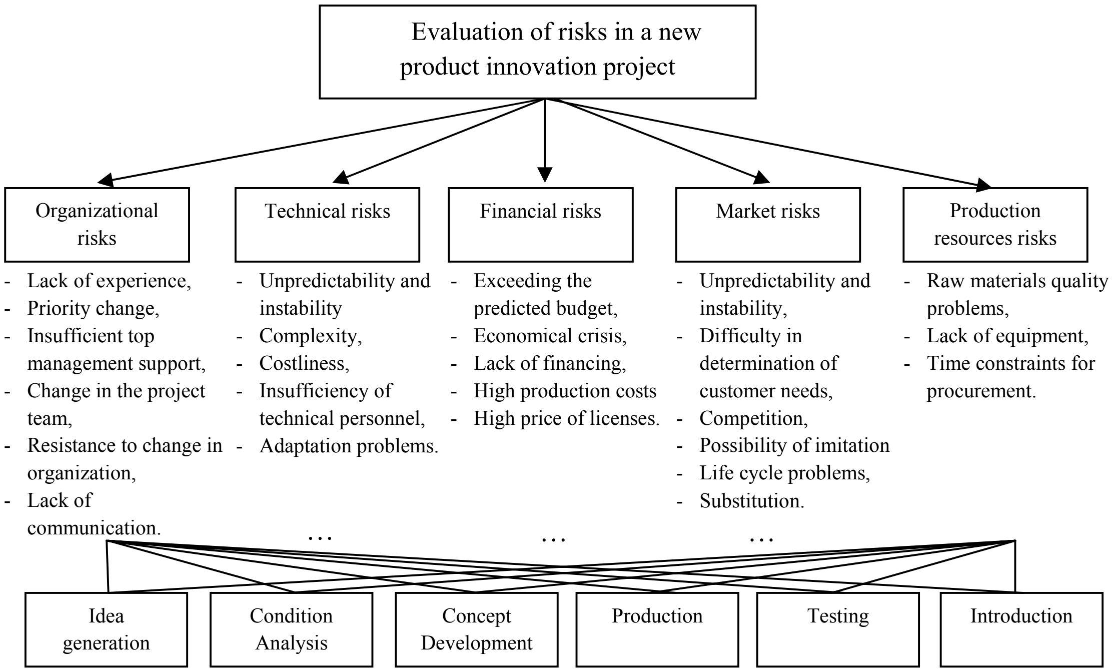

Fig. 1 Hierarchy for new product innovation process

3. *Evaluation of Phases*

The second objective of our study is to determine the risk of each phase. To do so, we evaluate each phase in terms of 25 different sub-criteria. The six phases are abbreviated as follows:

- Idea generation (IG)
- Condition Analysis (CA)
- Concept Development (CD)
- Production (P)
- Testing (T)
- Introduction (I)

TABLE VI
PRIORITY WEIGHTS OF RISK GROUPS AND SUB-CRITERIA

A (7%)	**B (25%)**	**C (20%)**	**D (35%)**	**E (13%)**
A_1 (14%)	B_1 (22%)	C_1 (26%)	D_1 (20%)	E_1 (48%)
A_2 (23%)	B_2 (19%)	C_2 (26%)	D_2 (18%)	E_2 (30%)
A_3 (14%)	B_3 (26%)	C_3 (19%)	D_3 (26%)	E_3 (22%)
A_4 (20%)	B_4 (17%)	C_4 (17%)	D_4 (12%)	
A_5 (12%)	B_5 (16%)	C_5 (12%)	D_5 (15%)	
A_6 (17%)			D_6 (9%)	

Table VII represents the weights of stages in respect to 25 sub-criteria.

According to the AHP methodology, the global weight of a stage is calculated as follows:

If x_{ij} is the weight of a phase in respect to the sub-criterion j belonging to the risk group i,

$$Global\ weight = \sum_i \left(\left(\sum_j x_{ij} * weight\ of\ sub-criteria_j \right) * weight\ of\ risk\ group_i \right) \quad (11)$$

This equation helps us to calculate the global weights of all the stages (Table VIII).

As a result, we can conclude that in the product innovation process in the pharmaceutical sector, the stages with the highest degree of risks are the “production” and the “introduction” phases with the risk degrees of 28% and 25%, respectively. The risk management departments of companies should pay attention to these phases.

IV. CONCLUSION

In times of increased competition and globalization, project success becomes even more critical to business performance. Risk management tools and techniques, which have been developed to improve project success, are used too little, and many still wonder how helpful they are. In this paper, we introduce a risk evaluation framework for the new product innovation process, which is applied for a pharmaceuticals company. As the result of the framework, we define the degree of risk of each risk group and related sub-criteria, which will guide the risk management departments of company on product innovation risks.

TABLE VII
WEIGHTS OF STAGES

	IG	CA	CD	P	T	I
A_1 (14%)	0.18	0.22	0.16	0.17	0,08	0,19
A_2 (23%)	0.01	0.03	0.11	0.22	0,25	0,38
A_3 (14%)	0.26	0.04	0.22	0.09	0,04	0,35
A_4 (20%)	0.06	0.06	0.35	0.20	0,06	0,27
A_5 (12%)	0.22	0.13	0.27	0.11	0,09	0,18
A_6 (17%)	0.18	0.15	0.22	0.12	0,14	0,19
B_1 (22%)	0.17	0.12	0.29	0.25	0,12	0,05
B_2 (19%)	0.02	0.11	0.35	0.35	0,10	0,07
B_3 (26%)	0.05	0.05	0.22	0.46	0,22	0,00
B_4 (17%)	0.00	0.00	0.26	0.48	0,26	0,00
B_5 (16%)	0.00	0.00	0.19	0.42	0,39	0,00
C_1 (26%)	0.08	0.10	0.14	0.26	0,17	0,25
C_2 (26%)	0.07	0.05	0.17	0.28	0,12	0,31
C_3 (19%)	0.08	0.08	0.12	0.34	0,06	0,32
C_4 (17%)	0.00	0.00	0.00	0.77	0,23	0,00
C_5 (12%)	0.00	0.00	1.00	0.00	0,00	0,00
D_1 (20%)	0.07	0.10	0.14	0.26	0,17	0,26
D_2 (18%)	0.21	0.24	0.24	0.02	0,02	0,27
D_3 (26%)	0.29	0.24	0.35	0.00	0.00	0,12
D_4 (12%)	0.00	0.00	0.00	0.00	0.00	1,00
D_5 (15%)	0.00	0.00	0.00	0.00	0.00	1,00
D_6 (9%)	0.00	0.00	0.00	0.00	0.00	1,00
E_1 (48%)	0.00	0.02	0.00	0.44	0,42	0,12
E_2 (30%)	0.00	0.00	0.00	1,00	0.00	0.00
E_3 (22%)	0.00	0.00	0.00	0,77	0,23	0.00

TABLE VIII
GLOBAL WEIGHTS OF STAGES

Stages	**IG**	**CA**	**CD**	**P**	**T**	**I**
Weights	0.08	0.08	0.18	0.28	0.13	0.25

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