A Multi-Criteria Project Assessment Framework for R&D Organizations in the IT Sector

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***Abstract*--he project selection is one of the most important problems in Information Technology (IT) organizations. Project evaluation criteria with the assigned weights are used to evaluate, prioritize and select projects. Project evaluation criteria should be aligned with the specific objectives of the organization and accurately reflect the opinion of experts. The purpose of this paper is to present a multi-criteria project assessment framework for Research and Development (R&D) organizations in the IT sector. The paper first generates a two-dimensional project selection framework which consists of project scoring and risk assessment hierarchies. The project scoring hierarchy consists of eight scoring criteria namely, strategic criteria, financial criteria, marketing criteria, technological criteria, human resources criteria, organizational criteria, development process criteria, and environment criteria. The project uncertainties are calculated by threats caused by eight major factors namely, technology factors, financial factors, marketing factors, human resources factors, organizational factors, development process factors, customer/user factors, and outsourcing factors. In this study, the judgments are elicited from 20 experts with using a pair wise comparison matrix and aggregated by taking the geometric mean of the individual judgments. The analytical hierarchical process (AHP) is applied to calculate the relative importance of the each criterion and sub criterion.**

I. INTRODUCTION

Many R&D organizations have carried out product development projects to enhance the technology management capabilities, and thus contribute to the goals of the company. One of the biggest challenges that an R&D organization has faced is to make the best project selection decisions. Poor decisions can have an enormous effect on implementation of corporate strategies. Therefore, creating an ability to evaluate project proposals to select the most appropriate projects must be the ultimate goal of an R&D organization.

A typical project scoring model covers a structured scoring process with a predefined set of criteria used to sort, prioritize, and select projects. This systematic approach evaluates proposals to make the best project selection decisions based on the overall objectives of the business and a number of factors that can potentially affect core operations of the company. In fact, project scoring should not only select the best projects among proposed alternatives but also show the strengths and weaknesses of them.

This paper presents a multi-criteria project assessment framework for IT product development organizations. The proposed framework analyses R&D projects based on two dimensions: the value of proposed projects and the impact of risks. In the literature, some studies classify risks under the project scoring criteria [1, 2, 3]. On the other hand, this study proposes a different approach so that R&D managers can make a distinction between value and uncertainty at project assessment stage.

The value of proposed projects is calculated by eight weighted scoring criteria namely, strategic characteristics, financial characteristics, marketing characteristics, technological characteristics, human resources, organizational characteristics, development process, and environment characteristics. The total effects of project uncertainties or risks are calculated by threats caused by eight major factors namely, technology factors, financial factors, marketing factors, human resources factors, organizational factors, development process factors, customer/user factors, and outsourcing factors. The proposed project selection framework consists of two different hierarchies namely, project scoring hierarchy and risk assessment hierarchy. The project scoring hierarchy is used to determine the value of a project proposal. Similarly, the risk assessment hierarchy is used to calculate the total effects of uncertainties in each project proposal.

The relative importance of project selection criteria is necessary to have adequate decision making capacity [4]. In this paper, judgments were obtained from the senior researchers and project managers who have worked at a government research center that consists of six different institutes. It is an invariable rule that weights have to reflect the relative importance of the individual criteria. Therefore, the AHP methodology is used to calculate the relative importance of criteria and the sub-criteria in accordance with the judgments of experts

The paper is organized as follows. The next section provides the literature review on project scoring criteria and project selection methodologies. Section 3 describes the method used in modeling. Section 4 presents the multi-criteria project assessment framework, explains the data collection methodology, calculates the relative importance of criteria weights, and finalizes the framework. Section 5 explains the implementation of the framework. Section 6 gives the conclusions.

II. BACKGROUND

Numerous studies have been conducted for R&D project selection. Table 1 summarizes the methods which have been applied for project selection problems in the literature. On the other hand, Table 2 gives the list of the criteria used in project scoring and selection problems.

Williams [5] introduces a basic decision model for R&D project selection. This model is consisted of three main parts: identifying the objectives and selection criteria, establishing the relative importance of and interactions between various factors and scoring the projects. The importance of this study come from the analysis of the results obtained from experts. It shows that each decision maker had a different perception of the relevance and importance of the factors to the objectives. Costello [6] uses the similar approach of Williams and proposes a more systematic system that gathers existing information from various parts of the R&D organizations. Four criteria namely, research need, staff capability, contribution to lab's stature and government interest research need are used in the decision making process.

Liberatore [7] focuses on technical, marketing/ distribution, manufacturing and financial categories to develop a combined AHP and spreadsheet expert support system for project prioritization and resource allocation. Mohanty [8] classifies the project selection criteria into two categories: intrinsic criteria and extrinsic criteria, and presents a model for evaluating project proposals with using normalized weights of the selection criteria. Lee and Om [9] examine the importance of the factors at both the private and public R&D institutes. They grouped fourteen items into the four factor categories namely, market characteristics, diffusion effect, technological characteristics and technological success. Danneels and Kleinschmidt [10] examine the relationship between five dimensions of product innovativeness consist of market familiarity, technological familiarity, marketing fit, technological fit, and new marketing activities and the decision to pursue or kill the project. Meade and Presley [11] focus on technical, marketing and organizational factors and discussed the use of the Analytic Network Process (ANP) to evaluate the value of competing R&D project proposals

TABLE 1 METHODS USED İN PROJECT SELECTİON PROBLEMS

Methods	Authors	Key Topics covered in the paper
Linear Programming	[26, 27, 28, 29]	R&D project selection problem
A zero one goal programming	[4, 18, 20, 21, 22, 23]	R&D project selection problem, IS project selection
Kolmogorov-Smirnov test	[9]	Importance of the factors used for the public and private R&D institutes.
Geometric average	[8, 12]	Criteria weights
AHP	[3, 12, 17, 19, 20]	R&D project selection problem, IS project selection, R&D project prioritization.
ANP	[11, 13, 23]	IS project selection, the evaluation of R&D projects with heterogeneous objectives.
Fuzzy logic	[14, 15, 16]	R&D project selection problem, the R&D optimal portfolio selection problem, hybrid fuzzy rule-based multi-objective framework
Manova, Anova	[2]	The importance of scoring criteria in the selection of IS projects

TABLE 2 SELECTED PROJECT SCORING CRITERIA IN THE LITERATURE

Criterion	Authors	Criterion	Authors
fits into overall strategy, contribution to organizational goals/objectives	[7, 2, 11, 25]	number and strength of competitors, market competitiveness, market environment, existence of champions	[8, 9, 11],
product life cycle	[11]	size/growth potentiality of market	[7, 9, 11, 25]
time to market	[11]	availability of market	[25]
fits technical capability, existence of required competence	[7, 11]	market share	[18, 28, 29]
resources, resources requirements and availabilities, manpower utilization	[2, 3, 4, 8, 11, 18]	sales	[18]
top management support, middle management support, interest of top management group	[2, 9]	degree of understanding consumers' needs	[9]
availability of infrastructure, physical facilities	[3, 18]	customer acceptance	[7]
project priority	[18]	opportunity for new technology/ market	[9]
suitability of the project to the research team, suitability of R&D support capabilities	[9, 26]	relatedness to previous R&D	[9]
clarity/rationality of goals/ plans	[9]	uniqueness of technology/ product	[9]
appropriateness of R&D period	[9]	technological advancement,	[26]
quality of technology/ product	[9]	potential to generate innovation	[3]
the utility	[27]	technological maturity	[3]
technological risk, development risk	[7, 27]	duality	[3]
risk spreading, risks response	[3, 8, 18]	patentability, patent position	[7, 9, 25]
risk spreading, risks response	[3, 4, 8, 18]	diffusion to science /engineering / industry	[9]
end-user understanding, cooperation, and commitment to project	[2]	capital investment required, availability of financial resources	[3, 7]
match with users' interest/work load	[2]	profit	[2, 26, 28, 29]
new industry standards	[2]	Return on Investment (ROI)	[4, 7, 25]
government policies and regulations	[1, 8, 11]	Net Present Value (NPV)	[11, 18]
socioeconomic climate	[8]	benefit/cost	[2, 22]
legal and technological implications	[2, 8]	budget	[18, 27, 28]
availability of needed technology	[2]	cost reduction	[27]
		payback period	[2, 7]

Silva et al. [3] prioritize the R&D projects in the aerospace sector according to the criteria of potential to generate innovation, technological maturity, duality, operational alignment, means availability, risk response, and opportune attendance. They applied the AHP method for the prioritization. Feng et al. [12] present an integrated decision method for collaborative R&D projects project selection. This method integrates AHP, scoring method and weighted geometric averaging method. Jung and Seo [13] explore the application of the analytic network process (ANP) approach for the evaluation of R&D projects that are elements of six national R&D programs with heterogeneous objectives.

In literature, non-statistical methods have also been used for project selection problems. Coffinl and Taylor [14] introduce a multiple criteria model for R&D project selection and scheduling using fuzzy logic and a standard beam search. For project portfolio problem, Carlsson at al. [15] present a fuzzy mixed integer programming model, Khalili-Damghani et al. [16] develop hybrid fuzzy rule-based multi-objective framework, and Huang et al. [17] present a fuzzy AHP and utilize crisp judgment matrix to evaluate subjective expert judgments.

Some research papers focus on Information System (IS) project selection [4, 18, 19, 20, 21, 22]. Muralidhar et. al. [19] present the application of AHP methodology to IS project selection problems. Schniederjans and Wilson [20] present an improved IS project selection methodology combining the AHP within a goal programming (GP) model framework. In this study, the AHP is first used to prioritize the set of IS projects and the resulting prioritization information is then used as a ranking scheme within the framework of a ZOGP model. Schniederjans and Santhanam [4] introduce the application of a zero-one goal programming model as a decision method for selecting information system projects. Lee and Kim [23] propose a methodology using analytic network process and zero one goal programming (ZOGP) in order to solve IS project selection problem. They make prioritization of six IS projects on basis of four criteria. Jiang and Klein [2] focus on the six subcategories of IS project evaluation criteria including financial, organizational, competing environment, technical, risk, and management. They statistically analyze the importance of those criteria in the selection of IS projects. Unlike these studies, Dey [24] uses the AHP to analyze industrial projects with respect to market, technicalities, and social and environmental impacts.

III. THE METHODOLOGY

The AHP, developed by Saaty in the 1970s, has been identified as an important mathematical technique used for multi criteria decision making. It needs a hierarchical structure to represent the decision problem and pairwise comparisons to determine relations within the structure [30]. The AHP allows decision makers to take a pair of elements and compare them on a single property without concern for other properties [31].

The AHP has been implemented in project selection problems [3, 12, 17, 19, 20]. Unlike most of the studies in the literature, this study uses AHP to solve two decision problems: 1) creating hierarchical decision making structures that assess project scoring criteria and project risk items separately; 2) determining relative importance of each scoring criterion and risk item in the hierarchical structures.

The AHP consists of three basic principles: decomposition, comparative judgments and synthesis of priorities [30]. The first principle helps decision makers to decompose a complex problem into a hierarchy of clusters or sub-problems. This study focuses on two problems related to project scoring criteria and project risk items, and decomposes them into less complex and more manageable sub-problems in order to build two separate hierarchies called "project scoring taxonomy" and "project risk assessment taxonomy".

The principle of comparative judgments helps decision makers and experts to construct pairwise comparisons of the relative importance of elements in the hierarchies. In this study, judgments are obtained from the senior researchers and project managers who have worked in the R&D department of a governmental research center. The experts separately examine the importance of each decision criterion in the hierarchies and make pairwise comparisons at each level by using the scale given in Table 3. Geometric mean method is used to aggregate these individual judgments for the final group decision.

Finally, the AHP synthesis the judgments obtained from the experts to provide a set of overall priorities for the hierarchy structures. The consistency of judgments is calculated with using the following formula [31].

$$A \times W = \lambda_{max} \times W \quad (1)$$

A shows the pairwise comparisons matrix, W is the normalized weight vector and λmax is the maximum eigenvalue of matrix A. The maximum eigenvalue is used to estimate consistency in a matrix. Formula 2 gives the consistency index (CI) measured for the inconsistency.

$$Consistencey\ Index\ (CI) = (\lambda_{max} - n)/(n-1) \quad (2)$$

The corresponding ratio (CR) is calculated by dividing the CI value by Random Consistency Index (RCI). Pairwise comparisons are considered to be consisted if the corresponding ratio (CR) is less than 10%.

TABLE 3 THE FUNDAMENTAL SCALE [30]

Intensity of importance on a absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor over activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity. i. then i has the reciprocal value when compared with i.	

IV. A MULTI-CRITERIA PROJECT ASSESSMENT FRAMEWORK

A. Framework design

1) Project scoring taxonomy

Determination of the criteria used in R&D project selection process is important [32]. Table 2 summarizes the project selection criteria studied in the literature. On the other hand, there are other indicators coming from the nature and characteristics of new products development process. For example, Meyer-Krahmer [33] lists innovation indicators as patents applied for and granted, revenues by selling patents, licenses and know-how, and output innovation intensity. Molina-Castillo et al. [34] emphasize the importance of three indicators, namely innovativeness to the firm, market turbulence, competitive intensity, market performance. According to the Balachandra and Friar [35], nature of the innovation, nature of the market and nature of the technology are the groups of the of contextual variables for successful new product innovation and R&D projects.

Throughout the literature review, there have been insufficient studies to establish a detailed taxonomy in project scoring. This paper presents a project scoring taxonomy that integrates existing research findings. The taxonomy that comprises hierarchically arranged categories is illustrated in Fig. 1. As seen in Fig. 1, the taxonomy can be decomposed into at most three category levels, where each category is a subset of the higher level category. The first level consists of eight set of criteria.

The strategic criteria set has three sub-categories: 1) strategic fit that means project's targets are consistent with the firm's overall business strategy , 2) the development or maintenance of a core competency or other sources of competitive advantage, and 3) the development or maintenance of a competency pertaining to future strategic options. The development or maintenance of a core competency sub-category which is a level 3 category consists of five sub-criteria: 1) development or maintenance of a critical technology or product, 2) cost reduction on an existing product, 3) quality improvement on an existing product, 4) product customization, and finally 5) productivity improvement in the organization.

Financial criteria set examines eight common financial indicators: 1) availability of financial resources, 2) appropriateness of project budget, 3) economic return, 4) benefit-cost (B-C) ratio, 5) payback period, 6) expected market share, 7) degree of dependence, and 8) revenues by selling patents, licenses and know-how.

Marketing criteria set is characterized by five sub categories: 1) market size, 2) market growth rate, 3) windows on new category, 4) windows on new market, and 5) estimate life of project output. Besides, technology criteria set consists of seven important criteria sets: 1) technology intensity, 2) newness of the product, 3) potential multi use or dual use of technology, 4) possibilities of licensing/registration/patenting of new products, 5) possibilities of creating a basis for other projects, 6) diffusion to science/ engineering/industry, and 7) technology maturity level.

As human resources (HR) criteria is extremely important in the success of software product development, it is located at the first level. This category consists of resource avaliability and resource capability. Resource capability criteria is decomposed into five different sub categories namely, "management experience and skills", "product development experience and skill", "engineering and technical experience and skills", "domain experience", and "marketing research skills and experience". On the other hand, development process category focuses on six basic criteria: 1) appropriateness of customers' needs, wants and preferences, 2) appropriateness of product scope, 3) appropriateness of product requirements, 4) appropriateness of project scope, 5) appropriateness of project structure, and 6) time-to-market. Finally, organizational category examines four sub-criteria: 1) degree of organizational commitment, 2) availability of product development facilities, 3) availability of marketing infrastructure, and 4) the knowledge management capability.

2) Project risk assessment taxonomy

Uncertainty is one of the most important difficulties stemming from R&D process. R&D project selection models should acknowledge and attempt to deal with the uncertainty [36]. Uncertainty in the R&D process indicates risk in the R&D project selection decision process [32]. There are various kinds of sources of uncertainty in product development projects [37, 38, 39, 40, 41, 42]. This paper presents a risk taxonomy created for the assessment of project proposals. The taxonomy illustrated in Fig. 2 comprises eight categories namely, technology related risks, financial risks, market risks, human resources risks, organizational risks, development risks, customer/user risks, and outsourcing risks. This taxonomy is decomposed into two category levels.

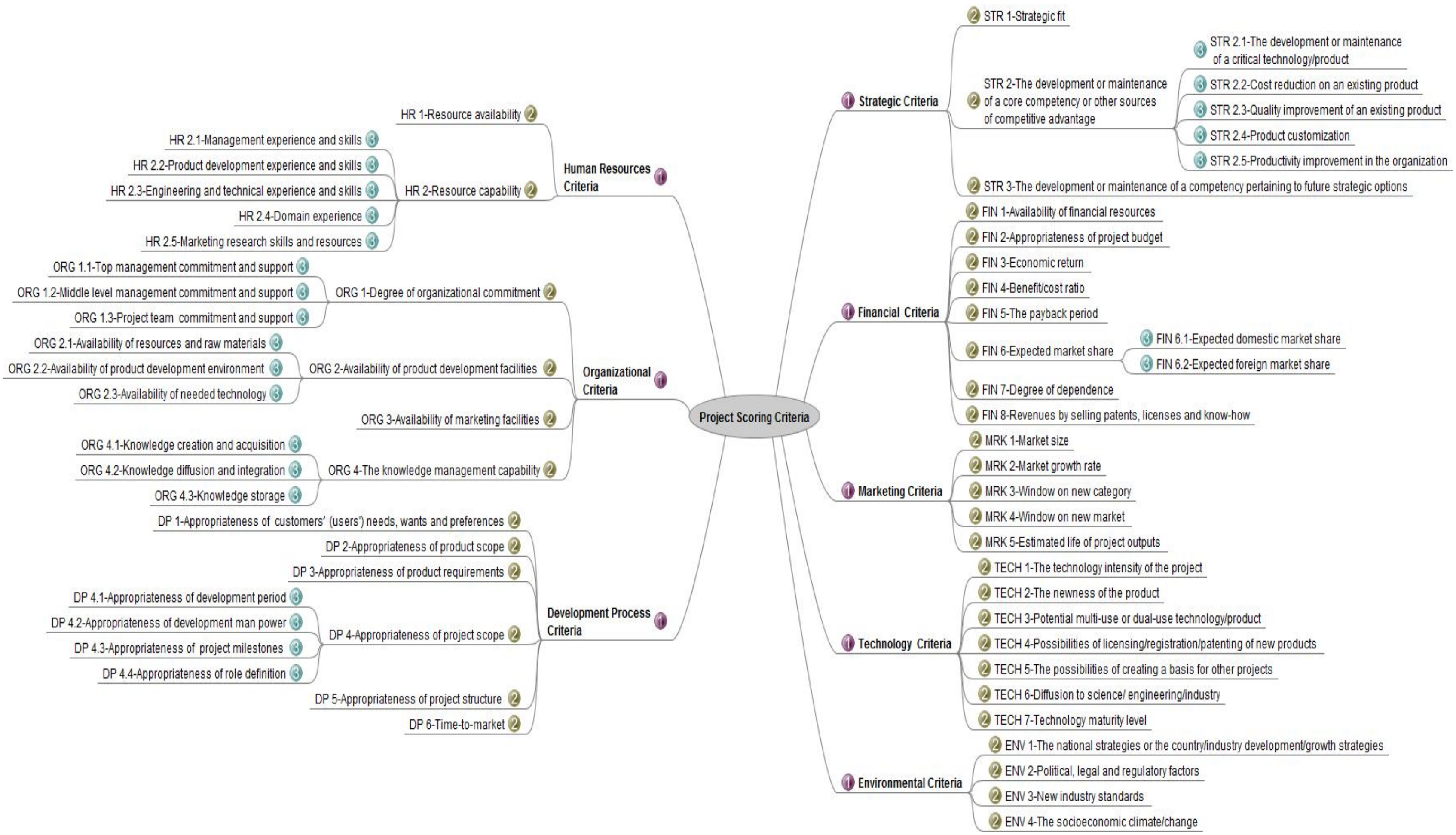

Fig. 1 Project Scoring Taxonomy.

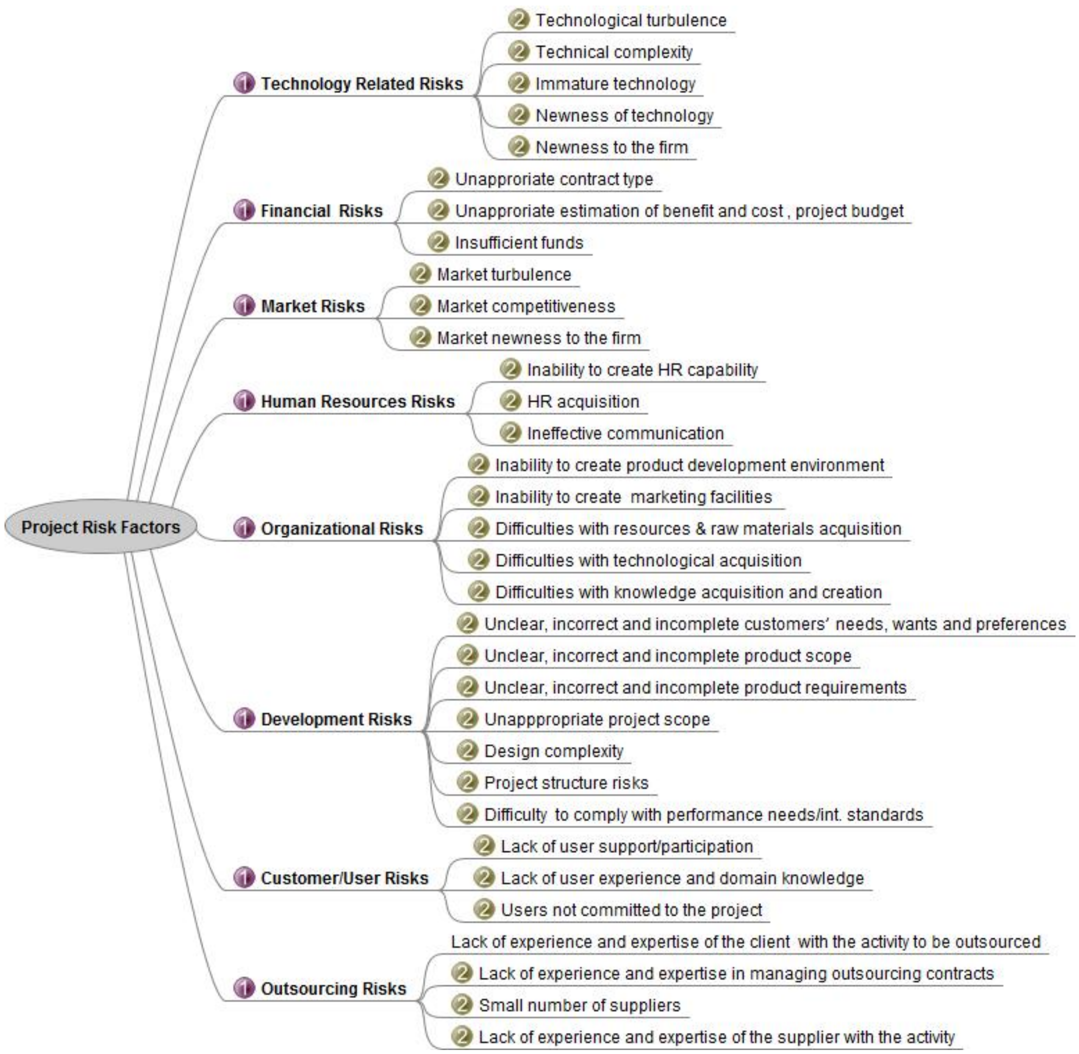

Fig. 2 Project Risk Assessment Taxonomy.

A suitable framework for the assessment of IT R&D projects requires both scoring and risk criteria. Some studies classify risks under the project selection or scoring criteria [2, 3]. On the other hand, R&D managers should make a distinction between opportunities and risks at project assessment stage. This paper presents a two-dimensional project selection framework that distinguishes between value and uncertainty. It aims to calculate relative importance of project scoring criteria and project uncertainties to establish an appropriate decision making model for R&D organizations. The decision problem is decomposed into the two separate the hierarchies given in Fig. 1 and Fig. 2. Once the project selection criteria and uncertainties are defined, weights or relative importance of them is calculated.

B. Data collection

A questionnaire including project scoring criteria and project risks was designed to assess relative importance of all the elements given in Fig. 1 and Fig. 2. The project scoring taxonomy consisted of 39 sub-criteria at level 2 and 25 sub-criteria at level 3 was assessed according to the level of importance to the organization. Project risks assessment taxonomy consisted of eight risk criteria at level 1 and 33 sub-criteria at level 2 was assessed with respect to the potential severity of the risks at project initialization stage.

Judgments were obtained from the senior researchers and project managers who have worked in IT business for over 15 years, and have specific expertise in the development of R&D products. The 20 experts from a governmental research center were asked to evaluate the proposed decision criteria for R&D project evaluation. The experts separately examined the importance of decision criteria and made pairwise comparisons at each level by using 1-9 scale given in Table 3. For each pair of criteria, the experts were asked to answer a set of questions such as "how important is criterion A respect to criterion B" and "how important is impact of risk A respect to impact of risk B". Geometric mean method was used to aggregate these individual judgments for the final group decision.

C. Framework implementation

At first, the AHP methodology was applied to calculate relative weights of each sub-criterion at level 1. The combined judgments were normalized and averaged to get the criteria weights. Table 4 gives the calculated weights of the criteria at the level 1.

As it is seen in table 4, strategy category is the most important category in the project selection decisions. This is followed by technology criteria, financial criteria and environmental criteria. The table also shows the importance of risk categories. Technology risk category stays at the top of the list. The financial risk category is the second important risk category in the project assessment stage. Marketing category is listed as the least important category in both taxonomy structures. Table 4 also gives the calculated CI and CR values. As these values are very close to zero, the judgments are found to be consistent and accepted for analysis.

Secondly, the AHP methodology was applied to calculate relative weights of each sub-criterion at level 2 and level 3. Fig. 3 illustrates the calculated weights of the elements in the Project Scoring Taxonomy. The consistency among pairwise judgments was checked for each decision level. According to the Fig. 3, all consistency values are very close to zero.

Similarly, Fig. 4 shows the calculated risk weights and the consistency values of the elements in the Project Risk Assessment Taxonomy.

TABLE 4 WEIGHTS OF THE ELEMENTS AT THE FIRST LEVEL

Project Scoring Taxonomy		Risk Taxonomy for Project Proposal	
Project Scoring Criteria	Weights	Project Risks	Weights
Strategic Criteria	0.207	Technology Risks	0.192
Financial Criteria	0.128	Financial Risks	0.182
Marketing Criteria	0.081	Market Risks	0.075
Technology Criteria	0.180	Human Resources Risks	0.112
Human Resources Criteria	0.097	Organizational Risks	0.110
Organizational Criteria	0.099	Development Process Risks	0.114
Development Process Criteria	0.088	Customer/User Risks	0.133
Environmental Factor Criteria	0.121	Outsourcing Risks	0.083
CI =0.00972 CR=0.00689		CI= 0.00686 CR=0.00486	

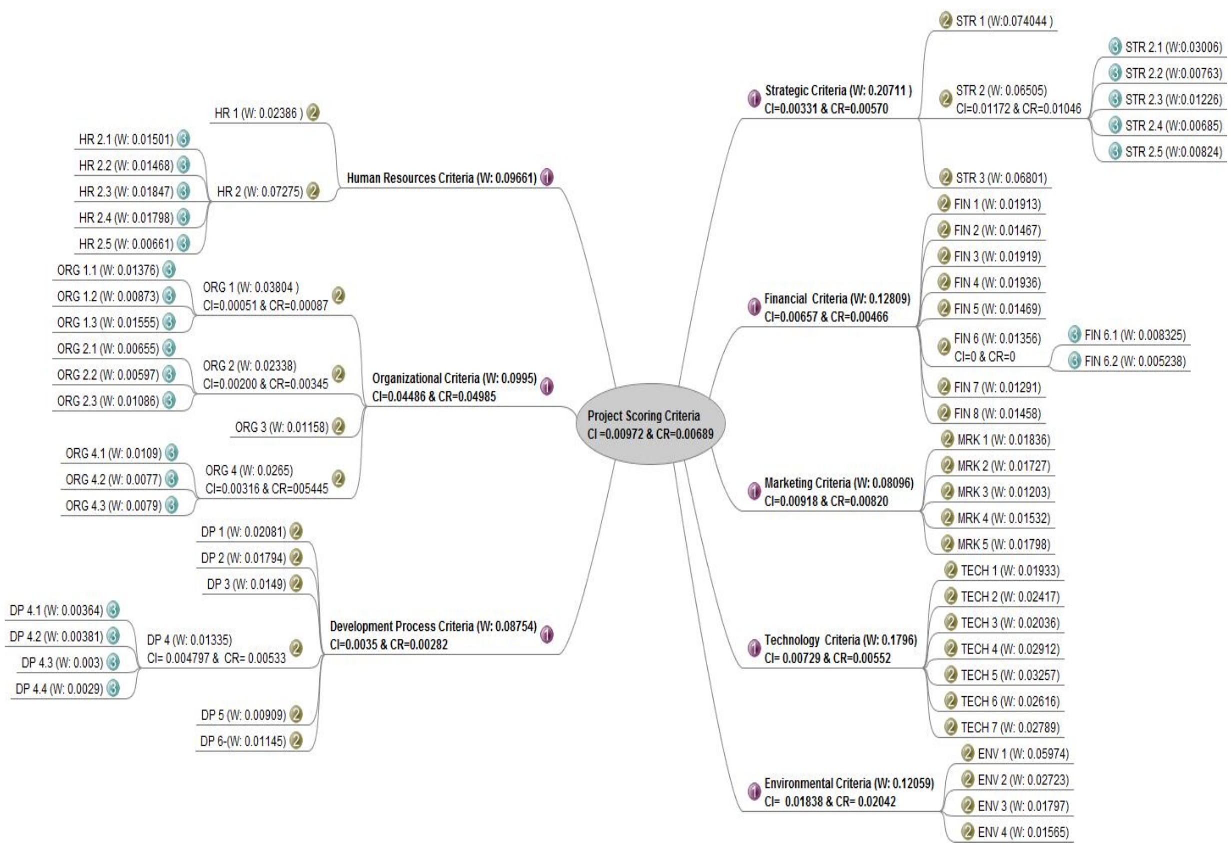

Fig. 3 Weights of the Project Scoring Taxonomy.

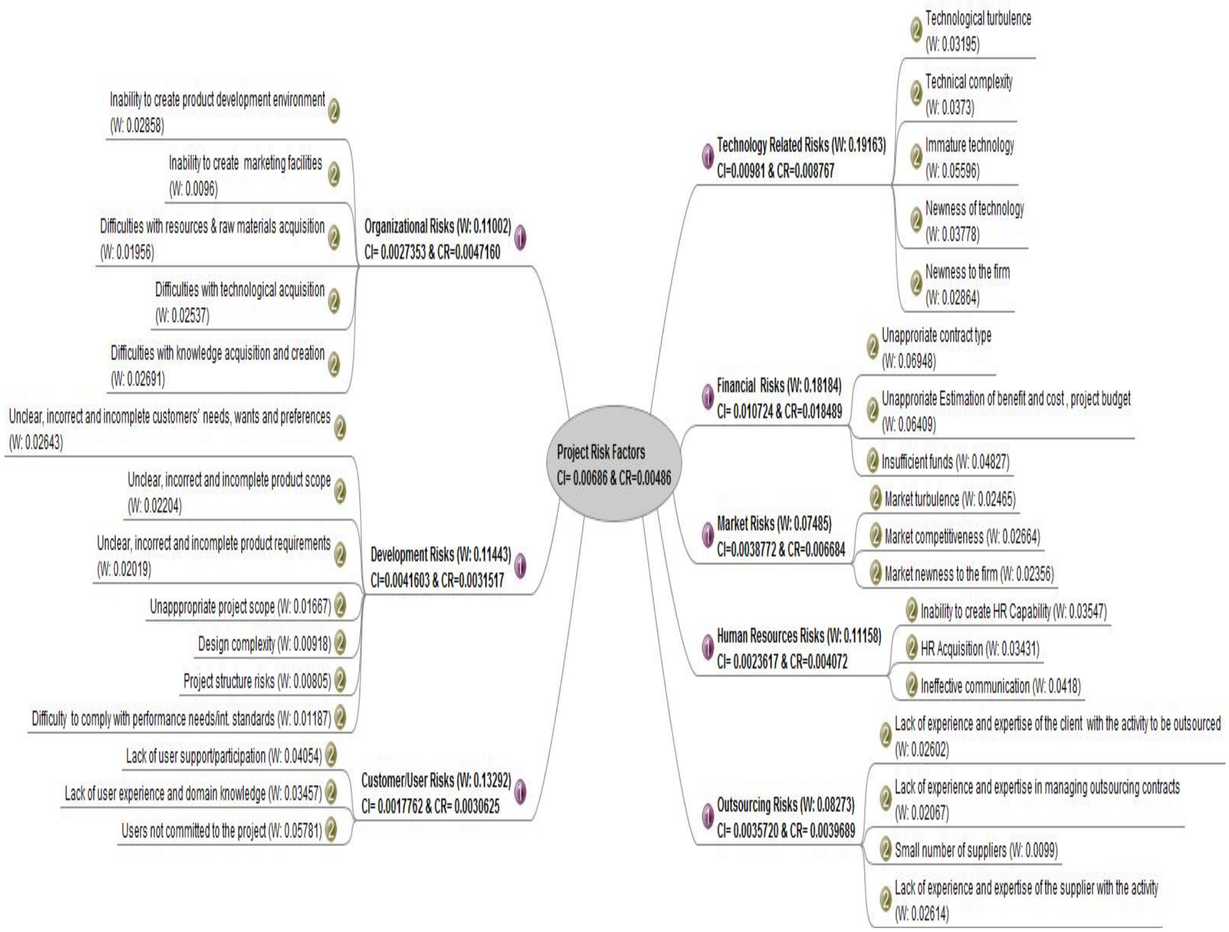

Fig. 4 Weights of the Project Risk Taxonomy.

D. The project scoring and risk assessment criteria list

Table 5 summarizes the top 25 list of project scoring criteria and project risks in order of the relative weights ranks. According to Fig. 3 and Table 5, the most important scoring criterion is the selection of projects to deliver the corporate strategy. The results stress that the goals of the project must be consistent with the firm's overall business strategy.

HR capability is the second most important criterion in the project scoring hierarchy. It is consisted of five sub-criteria: management experience and skills, product development experience and skills, engineering and technical experience and skills, domain experience, and marketing research skills and experience. This item indicates the degree of human resources capability in fulfilling the needs of the project. Similarly, according to Fig. 4, inability to create HR capability is ranked tenth in the project risk list. These results suggest that research organizations should establish a competency to develop existing resources and create new resources and capabilities in order to execute and manage their R&D projects.

Again, the third and fourth elements in the project scoring criteria are related to the strategy category. Experts who participated in the research emphasize that the development or maintenance of a competency pertaining to future strategic options is slightly more important than the development or maintenance of a core competency.

R&D activities in a governmental research center may contribute to national technological and scientific achievements or development and growth strategies of the country [36]. This paper also stresses the importance of these factors. National strategies or development/growth strategies of the country criterion is ranked fifth in the project scoring criteria list.

Organizational commitment is necessary for the success of R&D projects [37]. In this study, degree of organizational commitment is evaluated as one of the important criteria in the project selection decisions.

Three technology related criteria namely, possibilities of creating a basis for other projects, possibilities of licensing/registration/patenting of new products, and technology maturity level are ranked as the 7th, the 8th and 9th most important criteria in the project scoring criteria list respectively. The table 5 also emphasizes the importance of technology risks such that immature technology, newness of technology, technical complexity, technological turbulence, and technology newness to the firm are ranked within the top 15 risks among 33 project risk items. These results show that the technology is considered as not only a vital factor for the success of R&D projects but also an essential factor in selecting them.

According to the table 5, insufficient funds and inappropriate estimation of Benefit and Cost ratio and project budget are the two most important risk factors in the project selection problems. The project scoring criteria list in Table 5 also stresses the importance of these criteria. On the other hand, the same list shows that most of the financial criteria except Benefit and Cost ratio, economic return, and availability of financial resources are ranked toward to the end of the list.

TABLE 5 RANKİNG TABLE OF PROJECT SCORİNG CRİTERİA AND PROJECT RİSKS

Weight	Risk	Rank	Criteria	Weight
0.06948	Insufficient funds	1	SRT 1-Strategic fit	0.07405
0.06409	Inappropriate estimation of benefit and cost, and project budget	2	HR 2-Resource capability	0.07275
0.05781	Users not committed to the project	3	SRT 3-The development or maintenance of a competency pertaining to future strategic options	0.06801
0.05596	Immature technology	4	SRT 2-The development or maintenance of a core competency or other sources of competitive advantage	0.06505
0.04827	Inappropriate contract type	5	ENV 1-The national strategies or the country development/growth strategies	0.05974
0.0418	Ineffective communication	6	ORG 1-Degree of organizational commitment	0.03804
0.04054	Lack of user support/participation	7	TECH 5-The possibilities of creating a basis for other projects	0.03257
0.03778	Newness of technology	8	TECH 4-Possibilities of licensing/ registration /patenting of new products	0.02912
0.0373	Technical complexity	9	TECH 7-Technology maturity level	0.02789
0.03547	Inability to create HR capability	10	ENV 2-Political, Legal and Regulatory Factors	0.02723
0.03457	Lack of user experience and domain knowledge	11	ORG 4-The knowledge management capability	0.0265
0.03431	HR Acquisition	12	TECH 6-Diffusion to science/ engineering / industry	0.02616
0.03195	Technological turbulence	13	TECH 2-The newness of the product	0.02417
0.02864	Technology newness to the firm	14	HR 1-Resource availability	0.02386
0.02858	Inability to create product development environment	15	ORG 2-Availability of product development facilities	0.02338
0.02691	Difficulties with knowledge acquisition and creation	16	DP 1-Appropriateness of customers' needs, wants and preferences	0.02081
0.02664	Market competitiveness	17	TECH 3-Potential multi-use or dual-use technology	0.02036
0.02643	Unclear, incorrect and incomplete customers' needs, wants and preferences	18	FIN 4-Benefit/Cost Ratio	0.01936
0.02614	Lack of experience and expertise of the supplier with the activity	19	TECH 1-The technology intensity	0.01933
0.02602	Lack of experience and expertise of the client with the activity to be outsourced	20	FIN 3-Economic Return	0.01919
0.02537	Difficulties with Technological Acquisition	21	FIN 1-Availability of Financial Resources	0.01913
0.02465	Market turbulence	22	MRK1-Market size	0.01836
0.02356	Market newness to the firm	23	MRK5-Estimated life of project outputs	0.01798
0.02204	Unclear, incorrect and incomplete product scope	24/23	ENV 3-New industry standards	0.01797
0.02067	Lack of experience and expertise in managing outsourcing contracts	25	DP 2-Appropriateness of product scope	0.01794

The table significantly highlights the importance of lack of user commitment, lack of user participation or support and lack of user experience and domain knowledge. These results are consisted with the results of the other studies in the literature [42, 43].

Furthermore, another striking result of this study is that ineffective communication with the reminder risk items of human resources risk category is considered as a critical risk item that needs to be managed at the project initialization stage.

V. THE IMPLEMENTATION OF THE FRAMEWORK: A CASE STUDY

This paper also presents results of a case study conducted for evaluating the four R&D project proposals. The case study starts with introducing the phases of the project assessment and selection process. Then, it describes the implementation of the multi-criteria project assessment framework in an IT research institute.

The multi-criteria project assessment framework which was constructed in this paper presents the institutional project selection criteria and their weights in a research agency. In the case of the predefined institutional criteria, typical project assessment and selection process has seven steps: selection of the assessment methodology, definition of the appraisal committee, pre-testing of proposed projects, assessment of approved projects according to the multi-criteria project assessment framework, consolidation of assessment results according to the selected methodology, presentation of the consolidated results for final selection, and finally project selection.

This case study focuses on four R&D project proposals which passed the pre-test and got approved for the project appraisal process. Project proposal C aims to develop a software system for management and control of remote sensors. Project D, B and A develop complex systems that include software and electrical, electronic and mechanical hardware. Unlike the others, project A requires advanced mathematical and scientific knowledge to meet functional requirements. Weighted decision matrix was selected as the project assessment technique for this study. Each project scoring or risk criterion was measured on nine-point scale that ranges from 1 (much less important or much less effective) to 9 (extremely important or extremely effective).

In the first instance, four R&D project proposals were evaluated according to the project scoring taxonomy given in Fig. 1 and the project risk assessment taxonomy given in Fig. 2. At this stage, experts focused on two major issues: 1) the level of conformity of each project proposal to each scoring criterion and 2) the degree of uncertainty associated with each risk factor in each project proposal. For this purpose, they assigned numerical scores from 1-9 to each project scoring criterion and project risk item for each project proposal.

Subsequently, assessment results were consolidated with using the weighted decision matrix technique. After assigning scores for each project, the weighted score for each project was calculated by multiplying each criterion weight given in Fig. 3 and Table 5 by its score and adding resulting values. Similar to this, the weighted risk score for each project was calculated by multiplying each risk item weight given in Fig. 4 and Table 5 by its risk score and adding resulting values.

Finally, the consolidated results were presented for final selection. Fig. 5 presents a scatterplot diagram made of the project scoring value against the project risk value. The scatterplot was equally divided into four sections, namely: 1) class I-low risk low value, 2) class II- high risk low value, 3) class III-high risk high value and 4) class IV-low risk high value. Class IV is the most preferred category as it consists of high-value, low-risk projects. Conversely, Class II is the least preferred category since it comprises low-value, high-risk projects. Class I includes projects with low-value and low-risk. As seen in Fig. 5, Class I and Class IV are the most secure categories.

Furthermore, Class III indicates projects with high-value and high-risk. In reality, it is very hard to have projects with higher value and lower risk. In many cases, high returns are associated with high risk levels. Project value versus project risk matrix shows the tradeoff between expected project value and risk. It helps decision makers understand uncertainties and select the most appropriate project. With the help of additional analysis, the causes of project risks are identified. In cases where risks of the projects in Class III cannot be avoided, reduced or mitigated, the most appropriate project in Class I is selected.

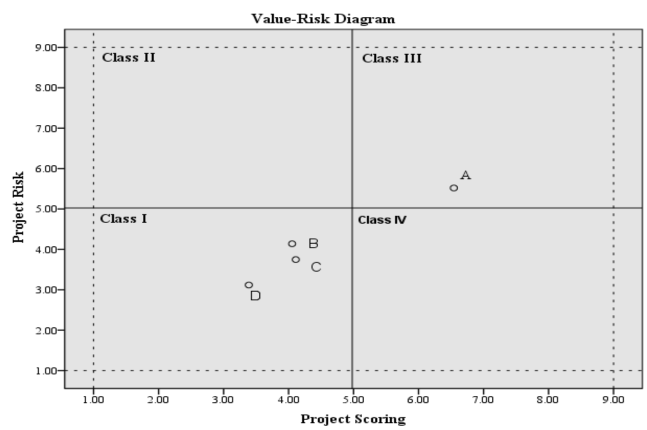

Fig. 5 Project Value Versus Project Risks.

As seen in Fig. 5, three project proposals are located in Class I category. These projects are relatively less valuable and less risky projects as compared to projects in Class III and Class IV. On the other hand, Class III offers project A with a substantially higher scoring value. Fig. 6 shows distribution of the risk factors in each project proposal. According to Fig. 6, technological and financial risk factors of project A have the highest risk weights. In the case of reducing, mitigating or managing these risks, project A produces the highest value. The other case, project C is the most appropriate solution.

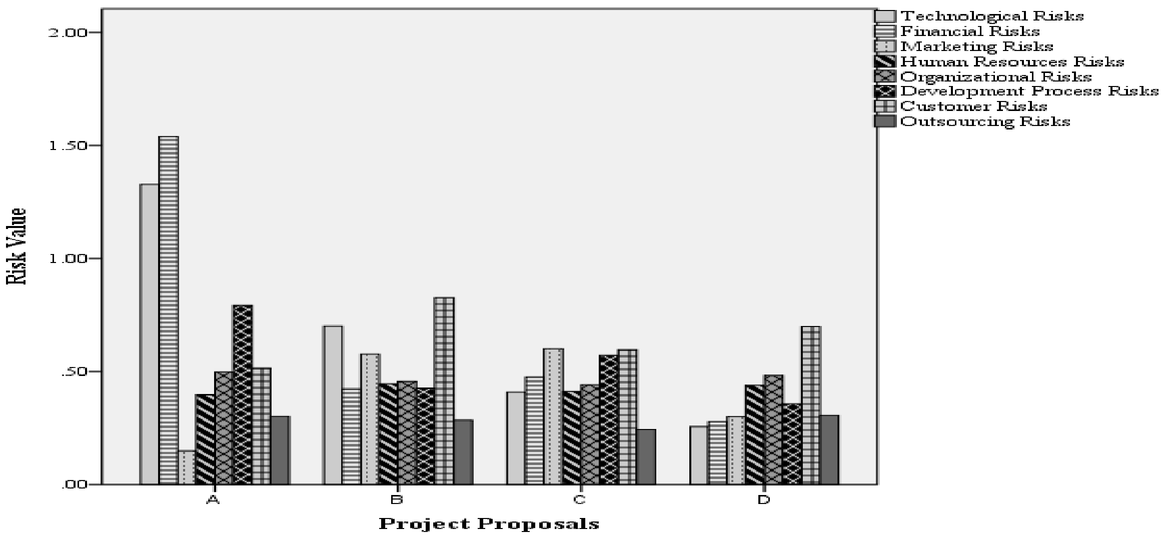

Fig. 6 Distribution of Risk Factors in Project Proposals.

VI. CONCLUSION

The purpose of this paper was to present a multi-criteria project assessment framework for R&D organizations in the IT sector. As a result of literature review, a two-dimensional project selection framework which consists of project scoring and risk assessment hierarchies was generated. The AHP method was used for two purposes; firstly to create hierarchical decision making structures that assess project scoring criteria and project risks items separately; and secondly to determine relative importance of each scoring criterion and risk item in the hierarchical structures.

20 expert judgments obtained from the experience researchers and project managers were aggregated for the final group decision by using geometric mean method. With the help of the AHP, the relative importance of project scoring and risk criteria was determined.

AHP was used because of the ability to 1) decompose complex decision problems into a systematic decision hierarchy, 2) evaluate relative priorities of factors, and 3) measure the consistency of decision maker‘s judgments. On the other hand, when the number of decision criteria increases the number of pairwise comparison matrix increases, and thus the AHP application becomes a quite time-consuming activity.

This study has several implications for R&D managers and researchers. First, the study generated two comprehensive and detailed lists for project selection problem. The project scoring criteria list ranks the 58 project scoring criteria based on their relative importance (weight). Similarly, the project risk criteria list ranks the 33 project risks based on their relative importance. These lists can help R&D managers outline what the government institutions expect from project proposals. In addition to this, they can help researchers and R&D project managers understand the main requirements of a good research proposal.

Second, the study provides R&D managers and researchers a comprehensive framework that can be used in project selection problems. With the help of this framework, project proposals are evaluated according to the project scoring and risk assessment criteria. This approach offers R&D managers to make a distinction between opportunities and risks at project assessment stage. In previous studies, risks were classified under the project selection criteria and included in the formula for calculating a project score. On the other hand, some risks can be eliminated or reduced. Even it can be managed. This framework helps decision makers expose the value of a project proposal, understand the negative impact of risks and make final assessment.

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