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التنبّؤ بالقدرة على الإبتكار في المشاريع الإستثمارية باستخدام خوارزمية الإعتقاد في الإحتمالات الغامضة وفق تقدير الوقت BIFPET: الإطار ودراسة حالة

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الخلاصة

تقترح هذه الورقة إطاراً على أساس الإحتمالات الغامضة الضبابية للتنبّؤ بالقدرة على الإبتكار في المشاريع الإستثمارية. يعتبر التنبّؤ بالقدرة على الإبتكار مهمة صعبة ويرجع ذلك إلى حقيقة أنه لايوجد أي مصدر للمعلومات بخلاف الحصول على المعلومات من تقرير جدوى المشروع الذي يتم عرضه قبل البدء في الإستثمار في المشروع. يدمج الإطار المقترح خمس مجموعات من العوامل وهي: العوامل المتعلقة بالموارد البشرية، والعوامل المتعلقة بالتكنولوجيا، العوامل المتعلقة بمميزات الشركة، العوامل المتعلقة بالبحث والتطوير وعوامل أخرى يتم تصنيفها تحت عنوان «العوامل المتنوعة». يستخدم هذا المقترح نسخة معدلة من خوارزمية «الإعتقاد في الإحتمالات الغامضة وفق تقدير الوقت» (BIFPET) لتجميع كل العوامل في التنبؤ المتماسك بالقدرة على الإبتكار. كما تم تقديم دراسة حالة لتوضيح مدى تطبيق وفعالية الإطار المقترح. وتشير نتائج هذه الدراسة إلى أن الإطار المقترح يمكن استخدامه للتنبؤ بالقدرة على الابتكار من المشروع الإستثماري. كما يمكن استخدامه من قبل المؤسسات والحكومات أو أصحاب المشاريع لفرز المشاريع الاستثمارية في ترتيب تنازلي فيما يتعلق بمستوى القدرة على الابتكار.

Predicting the innovation capability of investment projects using the BIFPET algorithm: a framework and case study

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ABSTRACT

This paper proposes a framework based on fuzzy probability for the prediction of innovation capability of an investment project. The prediction of innovation capability is a difficult task due to the fact that there exist almost no information source, except for a project feasibility report reviewed before the investment in the project. The proposed framework integrates five clusters of factors, namely; human resources related factors, technology related factors, firm-features related factors, R&D factors and other factors categorized under the heading of "miscellaneous factors". It uses an adapted version of the "belief in fuzzy probability estimations of time" (BIFPET) algorithm for synthesizing all factors into a cohesive prediction on innovation capability. A case study is presented to illustrate the applicability and effectiveness of the proposed framework. The results of this study show that the proposed framework can be used for the prediction of innovation capability of an investment project. It can be used by grant-giving institutions, governments or entrepreneurs to sort investment projects in descending order with respect to their innovation capability level.

Keywords: BIFPET algorithm; carpet industry; fuzzy logic; innovation capability; investment analysis.

INTRODUCTION

Nations with strong innovation capabilities tend to have high economic power. Governments in many countries consider innovation an important element of their progressive policies (Rampersad *et al.,* 2012). Innovation is a prerequisite for survival in today's competitive environment, and is quite significant for firms to sustain market share in the face of rapidly changing consumer tastes (Altuntas & Dereli, 2012). Innovation is defined differently, given different perspectives and disciplines (Damanpour & Wischevsky, 2006). However, a useful generalized definition is given by Kusiak (2009), who declares innovation to be "an iterative process aimed at the creation of new products, processes, knowledge or services by the use of new or even existing knowledge". As with innovation, there are different definitions of innovation capability in the literature because there is no perfect consensus about either the logic behind, or a framework for effective innovation. Details on these definitions can be found in Martinez-Roman *et al.* (2011). Importantly, Terziovski (2007) emphasized that "innovation capability provides the potential for effective innovation". Herein, therefore, innovation capability is defined as "the ability to survive and support innovation by using all resources related to human factors, manufacturing, research and development (R&D), marketing, and other factors demonstrated to sustain innovation."

Technology innovation has become an important economic weapon among companies and countries (Sun *et al.,* 2012). Therefore, the evaluation of the innovation capability of any technology endeavor is increasingly valued. Lixia (2010) emphasizes that there are three significant ways to evaluate the technology innovation capability: (1) from the aspect of investment (such as R & D costs and strength of inputs, proportion of the technical staff, etc.), (2) in terms of output (such as the number of patents, the number of cited patents, etc.), and (3) from the actual economic results (directing measurement on economic and social benefits of innovation). In this study, we focus on the first method, namely the aspect of investment and its capacity for predicting the innovation capability of investment projects.

The decision to invest in a project involves asking and answering many questions that are broadly known and understood to be crucial. How long is the payback period? What is the return on investment? What is the amount of existing and future demand for the project deliverable? In one of our preliminary studies (Altuntas & Dereli, 2012), we proposed an evaluation index system to answer "What is the technology commercialization potential of an investment project." In addition to technology commercialization potential of investment project, as we discussed in one of our preliminary studies (Altuntas & Dereli, 2012), we also mentioned that one of the important factors that should be considered for investment project for future studies is innovation capability potential. Therefore, this paper focuses on the question: "What is the innovation capability potential of the investment project?" Assessing innovation capability potential gives clues about the future of the investment project and the results of the investment project, such as whether the value of the technology itself will be high. Through the proposed framework, a decision maker can provide both objective and subjective knowledge about the factors that are related to innovation in the project. A potential application of the proposed framework could be for grant-giving institutions or governments, which generally desire that their financial incentives result in the most innovation possible. The proposed framework would allow these entities to sort project application in descending order with respect to their innovation capability level. In addition, companies that develop their innovation potential gain a competitive power against their competitors (Perez-Cano, 2013). Therefore, innovation capability of any investment project should be predicted prior to the investment, using the best information and tools available. This study attempts to address this opportunity.

The BIFPET algorithm estimates the value of activities based on belief functions and fuzzy logic theory for integrating estimates into a model in the presence of ambiguity. This method makes it possible to use subjective and objective information from different sources that have different levels of "belief" in the probability estimates given. For the purposes of the model proposed herein, the BIFPET algorithm allows for consulting the investor, decision makers who affect the investor, and experts in investment sector for opinions about factors that predict innovation capability.

The remainder of this study is organized as follows. Section 2 reviews literature related to innovation capability and fuzzy logic. The proposed framework is presented in Section 3. An application for the prediction of innovation capability of an investment project in the carpet industry is presented in Section 4. Finally, Section 5 gives conclusions of this study.

LITERATURE REVIEW

Numerous empirical studies have been conducted in the literature to examine innovation capability with respect to different aspects. Among these studies, Lawson & Samson (2001) proposed an innovation capability model based on seven elements, namely vision and strategy, harnessing the competence base, organizational intelligence, creativity and idea management, organizational structures and systems, culture and climate, and management of technology for organizations. The aim of the proposed model is to describe the ability of high-performing innovators to achieve effective performance. Nassimbeni (2001) conducted an empirical research and used a logistic regression model to point out the export activity of small manufacturing firms by analyzing technological and innovation capacity-related factors. Romijn & Albaladejo (2002) measured innovation capability in small UK electronics and software firms. Guan & Ma (2003) used seven innovation capability dimensions (learning, R&D, manufacturing, marketing, organizational, resource allocating and strategy planning) to explore the relationship between innovation capability and export performance for Chinese exporting firms. Subramaniam & Youndt (2005) provided a framework to find the effect of intellectual capital on the types of innovation capabilities, namely radical and incremental innovative capability. Assink (2006) tried to find the reason of why disruptive innovation is not done by large firms generally and the factors which do not support disruptive innovation. Koc & Ceylan (2007) examined the factors which affect the innovative capacity in large-scale companies. Sun (2009) tested the relationship national culture and national innovation capability. Elmquist and Masson (2009) suggested a framework for evaluation of R&D project with respect to innovation capability. Wonglimpiyarat (2010) developed an index for the assessment of innovation capability of nations. Ngo & O'Cass (2012) modeled the roles of both innovation capability and marketing capability in mediating the relationship between market orientation and some specific performance outcomes. Laakso *et al.* (2012) focused on the SME's ability to carry out innovation and new value creation in a network. Ural & Acaravci (2012) explained the role of the firms' innovative capabilities and the appropriability regime level (ability to profit from innovations) as potential antecedents of the firms' internationalization. Tseng *et al.* (2015) considered three criteria, namely degree of innovativeness of R&D products, intensity of collaboration with others and R&D knowledge sharing ability to measure innovation capability for service innovation in the hotel industry.

Furthermore, the effect of some factors on firm innovation capability is examined in the literature, such as tacit knowledge transfer (Cavusgil *et al.,* 2003), different types of technology sourcing, namely partnership-based, market-based, value-chain-based and internal sourcing (Zhao *et al.,* 2005), knowledge management (Yang *et al.,* 2006), knowledge sharing (Lin, 2007), innovation strategies, market orientation and innovation capability (Akman & Yilmaz, 2008). On the other hand, the effect of innovation capability on some factors is researched as well. For example, the effect of innovation capability on firm performance (Sher & Yang, 2005), export performance (Korkmaz *et al.,* 2009), long-term corporate growth in high technology firms in China (Yang, 2012) is examined.

Several researchers try to find the relationship between innovation capability and other factors. Tasmin & Woods (2007) analyzed the relationship between corporate knowledge management and the firm's innovation capability. Koc (2007) examined organizational determinants of innovation capacity in software companies. Xu *et al.* (2008) conducted a research to find association between the network structure and participating firms' innovative capabilities. Numprasertchai *et al.* (2009) tried to find the relationship between the knowledge creation process and innovation capability and includes two critical factors, namely organizational strategy and incentive. Calantone *et al.* (2002) examined the relationships among firm performance, firm innovativeness, and learning orientation. Poon & MacPherson (2005) analyzed the relationship between Asian firms' technological and non-technological strategies and innovation capability.

In addition to above studies, as with this paper, fuzzy logic based studies are also conducted in the literature. Among these studies, Lu *et al.* (2007) applied fuzzy set theory for evaluating firm technological innovation capability. Wang *et al.* (2008) used a fuzzy measure and non-additive fuzzy integral method for evaluating firm technological innovation capability under uncertainty in hi-tech firms. Dereli *et al.* (2011) proposed a framework and used fuzzy beliefs to enhance innovation capabilities of firms by considering the collaboration of sellers and buyers. Alam (2011) investigated how entrepreneurs' personality traits affect firm innovation capability. He found that personality traits of an entrepreneur had significant impact on the firm innovation capability in Malaysia by using multiple regression analysis. Kittilaksanawong & Ren (2013) discussed the evolution of organizational forms over time in collaborating with intermediary organizations to access the necessary external resources and capabilities and to build up their necessary innovation capability. They presented cases of manufacturing small- and medium sized enterprises from China's Zhejiang province. Yang *et al.* (2015) proposed an evaluation indicators system of innovation capability using analytic hierarchy process and the variation coefficient method.

Researchers generally conducted empirical studies to measure innovation capability with respect to different aspects of organizations. However, as can be seen from above discussed literature from different aspects, there is no study providing a model that predicts innovation capability of an investment project. The factors affecting innovation capability were selected based on the empirical studies conducted in the literature and used to complete the proposed model. The proposed framework and algorithm used in this paper is the first known attempt for the prediction of innovation capability of investment projects. Details and discussions on innovation capability can also be found in ERIA Research Project Report (2010) and Terziovski (2007).

THE PROPOSED FRAMEWORK

In this section, the proposed framework is introduced in detail. To show how the proposed framework works, the section is divided into two subsections, namely; "Criteria" and "Belief in Fuzzy Probability Estimations of Time (BIFPET) algorithm". The subsection entitled "Criteria" presents criteria considered for the development of the framework and introduces the formulation used for the proposed framework. The subsection entitled: "Belief in fuzzy probability estimations of time (BIFPET) algorithm" summarizes the basic logic behind the algorithm for the prediction of 'innovation capability' of investment projects.

Criteria

There are numerous criteria that must be considered during the evaluation of innovation capability, and most of them are fuzzy and conflict with one another (Wang *et al.*, 2008). There are different assets, resources, and capabilities for the success of an innovation as well (Guan *et al.,* 2006). Therefore, this study uses criteria that are most highlighted in the literature for innovation capability and uses a fuzzy logic-based approach to mitigate the ambiguity of both the data and the criteria. The proposed innovation capability framework is given in Figure 1. There are 18 factors based on the innovation capability literature in the proposed framework. These factors are divided into five main clusters, and each factor cluster consists of a number of sub-factors. The main factor clusters are: human resource factors (six sub-factors), technology factors (two sub-factors), firm features factors (two sub-factors), R&D factors (four sub-factors) and a miscellaneous factors category (four sub-factors). The value obtained from formula-1 shows us the innovation capability index of the investment project. Therefore, investment projects can be ranked with respect to their innovation capability potential, and then the most innovative project among any number of alternatives can be quantitatively supported through the use of this index value. It is prudent to note here that the index value derived by formula 1 serves to compare projects' relative innovation capabilities against one another, and should not be construed as a rating against an absolute "innovation capability" scale.

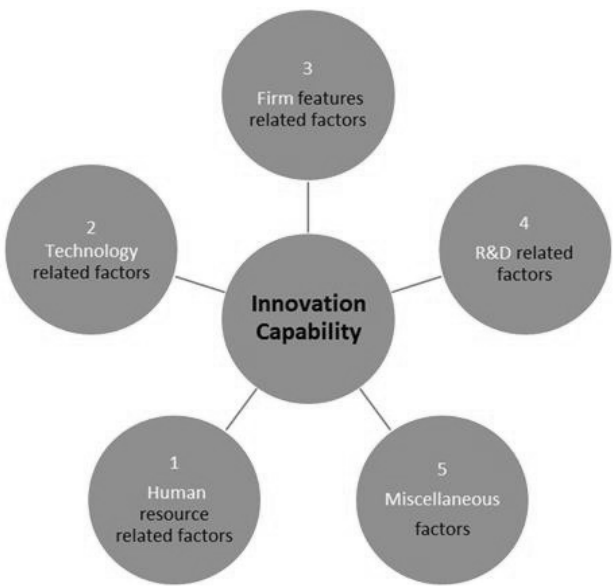

Fig. 1. Proposed framework for the prediction of innovation capability

To understand the proposed framework clearly, the following formulation is developed:

$$IC = W_{HR} \times V_{HR} + W_{TR} \times V_{TR} + W_{FF} \times V_{FF} + W_{RD} \times V_{RD} + W_{MS} \times V_{MS} \quad (1)$$

where:

IC: Innovation capability

V_{HR}: Value of human resource factors

V_{TR}: Value of technology factors

V_{FF}: Value of firm features factors

V_{RD}: Value of R&D factors

V_{MS}: Value of miscellaneous factors

W_{HR}: Weight of human resource factors

W_{TR}: Weight of technology factors

W_{FF}: Weight of firm features factors

W_{RD}: Weight of R&D factors

W_{MS}: Weight of miscellaneous factors

It should be noted that the total of all the factors' weights ($W_{HR}+W_{TR}+W_{FF}+W_{RD}+W_{MS}$) must be 100%. All the above factors composed of some sub factors. Below are the formulations for each of the given factors.

$$V_{HR} = W_{HR1} \times HR_1 + W_{HR2} \times HR_2 + W_{HR3} \times HR_3 + W_{HR4} \times HR_4 + W_{HR5} \times HR_5 + W_{HR6} \times HR_6 \quad (2)$$

where:

HR_1: Trained personnel in the field of information technology

HR_2: Knowledge of foreign languages

HR_3: Employee which has doctoral, graduate and undergraduate degree (Engineering Area)

HR_4: Expected annual expenditure strength for human resources

HR_5: The presence of top management' experience in an international companies

HR_6: The percentage of presence of personnel' experience

$R=\{i|i= 1,2,\ldots, 6\}$

W_{HRi} shows the weight of i^{th} factor. $\forall i \in R$.

The sum of the factors' weights should be 100%.

$$V_{TR} = W_{TR1} \times TR_1 + W_{TR2} \times TR_2 \quad (3)$$

where:

TR_1: Range of new products and services

TR_2: Improvements in cost or technical attributes of existing processes, services and products

$I=\{j|j= 1,2\}$

W_{TRj} shows the weight of j^{th} factor. $\forall j \in I$.

The sum of the factors' weights should be 100%.

$$V_{FF} = W_{FF1} \times FF_1 + W_{FF2} \times FF_2 \tag{4}$$

where:

FF_1: Firm Size

FF_2: Partnership and cooperation agreements with other firms, universities or institutions

F={c|c= 1,2}

W_{FFc} shows the weight of c^{th} factor. $\forall\ c \in F$.

The sum of the factors' weights should be 100%.

$$V_{RD} = W_{RD1} \times RD_1 + W_{RD2} \times RD_2 + W_{RD3} \times RD_3 + W_{RD4} \times RD_4 \tag{5}$$

where:

RD_1: Rate of Total R&D expenditure in each year

RD_2: The presence of the Technology Watching Department

RD_3: Percentage of total full-time and part-time R&D personnel in the company

RD_4: Per capita computer

T={t|t= 1,2,…, 4}

$W_{RD\,t}$ shows the weight of t^{th} factor. $\forall\ t \in T$.

The sum of the factors' weights should be 100%.

$$V_{MS} = W_{MS1} \times MS_1 + W_{MS2} \times MS_2 + W_{MS3} \times MS_3 + W_{MS4} \times MS_4 \tag{6}$$

where:

MS_1: The presence of the Internet site to gain expectation and perception from customers

MS_2: Percentage of the number of employees who work in marketing department

MS_3: Expected annual expenditure strength for marketing

MS_4: Number of universities and research centers in a region which firm will be established.

H={h|h= 1,2,3,4}

W_{MSh} shows the weight of h^{th} factor. $\forall\ h \in H$.

The sum of the factors' weights should be 100%.

Formulas 1 through 6 estimate the innovation capability level of an investment project. However, the most important and difficult task is to find the values to be used in formulas 2 through 6 and these values can be obtained from different sources with high amounts of ambiguity in belief values. Herein, we use the BIFPET algorithm to obtain expected value for each factor. The input data for the BIFPET algorithm is collected as follows. Firstly, the investor estimates factor weights that correspond to his or her current investment criteria. Secondly, the decision makers who affect the investor predict Optimistic (O), Most Possible (Po) and Pessimistic (Pe) value for each factor by negotiation. Then, these decision makers define fuzzy probabilities for each (O), (Po) and (Pe) value. Lastly, the expert in the field of the investment assigns a value, which estimates the degree of belief for a given probability value. During this exercise, the expert can consider the success of the investor's previous investments or his/her understanding of or intuition about belief in the probability assigned by investor and the reason of the probability value assigned. The aim of this belief value is to reflect the expert's level of confidence in the decision-making process. To sum up, the BIFPET algorithm incorporates (1) factor weights from the investor, (2) "O", "Po" and "Pe" values and related probability values for each of them from the decision makers, and (3) belief measures obtained from the industry expert to estimate confidence in the decision-making process.

Details on each factor and their formula are briefly introduced below to understand calculation process clearly.

Human resources related factors (HR)

Many studies emphasize that human resources related factors affect innovation capability, such as Martinez-Roman, *et al.* (2011), Chen & Chen (2006), Atanasiu *et al.* (2009), Chen & Xu (2009), and Yilin *et al.* (2010). Kaufman *et al*. (2000) underlined that innovative firms require well-trained employees to continually improve products and processes. Baldwin & Johnson (1996) also indicate that innovative firms give more importance to human resources than less-innovative firms. Herein, we constructed human resource factors using the six measures given below.

1) Trained personnel in the field of information technology (HR_1) is measured on the basis of the percentage of the existing certificates held that relate to information technology and are given from universities or other educational institutions. To calculate this factor, we use the following formula:

   HR_1 = Total number of employees holding certificates in the field of information technology (HR_{11}) / Total number of employees in the firm (HR_{12})

2) Knowledge of foreign languages (HR_2) is measured on the basis of the percentage of employees who know and can use foreign languages. The following formula is used for the calculation:

HR_2 = Total number of employee who know and use foreign languages (HR_{21}) / HR_{12}

3) The percentage of employees holding doctoral, graduate and undergraduate degrees in STEM disciplines (science, technology, engineering and math). HR_3 is measured by using following formula:

$$HR_3 = (HR_{\mathrm{DR}} + 0.5 \times HR_{\mathrm{GR}} + 0.25 \times HR_{\mathrm{UG}}) / HR_{12}$$

where,

HR_{DR}: Total number of employees holding doctoral degrees.

HR_{GR}: Total number of employees holding Master's degrees.

HR_{UG}: Total number of employees holding baccalaureate degrees.

4) Expected annual expenditure strength for human resources (HR_4) is measured on the basis of the percentage of the total annual expenditure for human resources. Annual expenditure for human resources includes all of the expenditures related to human resources, such as expenditures for organizing educational activities for the development of R&D personnel from STEM disciplines, staff rewards and promotions, and other mechanisms for development and rewarding of employees. HR_4 is measured by:

   HR_4 = Expected annual expenditure for human resources (HR_{41}) / Total annual expenditure (HR_{42})

5) The presence of top management experience in international companies (HR_5) is measured by using following formula:

   HR_5 = Total number of top management staff with experience in international companies (HR_{51}) / Total number of top management staff (HR_{52})

6) The percentage of presence of personnel external experience (HR_6) is measured by

   HR_6 = Total number of employees with experience in other firms (HR_{61}) / (HR_{12})

Technology related factors (TR)

Taskin *et al.* (2004) emphasize that "the ones which have invested in the accurate areas of technology during the last few decades became the developed countries and the biggest firms." Therefore, technology which will be invested in is very important for innovation. In this study, we use two important technology factors that affect innovation capability: the range of new products and services (TR_1) and improvements in cost or technical attributes of existing processes, services and products (TR_2). The economic significance of several generic technologies is shown in Table 1 by the report of New technologies in the 1990s (OECD, 1988). These technologies are space, nuclear, bio-tech, materials and information (electronics, computer and telecommunication). As can be seen from Table 1, the economic significance of information technology has the highest value among technologies with respect to two factors considered. Herein, we use following values for TR_1 and TR_2 based on Table 1.

$$TR_1 = \begin{cases} \frac{2}{10}, if\ invested\ in\ Space\ Tech. \\ \frac{2}{10}, if\ invested\ in\ Nuclear\ Tech. \\ \frac{4}{10}, if\ invested\ in\ Bio-Tech. \\ \frac{4}{10}, if\ invested\ in\ Materials\ Tech. \\ \frac{9}{10}, if\ invested\ in\ Information\ Tech. \end{cases}$$

$$TR_2 = \begin{cases} \frac{2}{10}, if\ invested\ in\ Space\ Tech. \\ \frac{1}{10}, if\ invested\ in\ Nuclear\ Tech. \\ \frac{3}{10}, if\ invested\ in\ Bio-Tech. \\ \frac{4}{10}, if\ invested\ in\ Materials\ Tech. \\ \frac{9}{10}, if\ invested\ in\ Information\ Tech. \end{cases}$$

Table 1. Rating of economic significance of several generic technologies*

Factors	Space	Nuclear	Bio - Tech.	Materials	Information
Range of new products and services (TR_1)	2	2	4	4	9
Improvements in cost or technical attributes of existing processes, services and products (TR_2)	2	1	3	4	9

**A value of 10 represents the highest rating and a value of 1 the lowest.*

Some investment projects can be related to more than one technology class. Herein, the related technology class that has highest score should be used.

Firm features factors (FF)

Firm features factors are measured by two factors, namely firm size (FF_1), and partnership and cooperation agreements with other firms, universities or institutions (FF_2). The measures of these factors are given below:

Marques & Ferreira (2009) highlighted that the size of a firm affects innovation capability. Firm size (FF_1) is measured by the total number of employees, who work in firm (HR_{12}). FF_1 is divided into four categories. We give following scores for each class with respect to firm size.

$$FF_1 = \begin{cases} 0.2, if\ labor\ force\ \leq 9 \\ 0.4, if\ labor\ force\ is\ between\ 10\ and\ 99 \\ 0.6, if\ labor\ force\ is\ between\ 100\ and\ 249 \\ 1, if\ labor\ force\ is\ higher\ than\ 250 \end{cases}$$

People tend to have more information sharing and interactions when they work together. This can make them to be more willing to accept new ideas and engage in innovative activities (Chen & Yang, 2009). Myers (1984) emphasizes the combination of entrepreneurial, managerial and technological roles for successful technological innovation. Partnership and cooperation agreements also help knowledge sharing. The findings of Lin (2007) show that 'knowledge sharing' affect a firm's innovation capability positively. Therefore, partnership and cooperation agreements among firms increase their innovation capability and activity. Marques & Ferreira (2009) also emphasized that partnership and cooperation agreements with other firms, universities or institutions (FF_2) affect the innovation capability positively. We give "0.1" score for each partnership or cooperation agreement. We give 0 for no partnerships or cooperation agreements and 1 for 10 or more partnerships or cooperation agreements.

It should be noted that the factor of "exporting firm or not" is related to firm features, but Marques & Ferreira (2009) concluded that an exporting firm does not have greater innovation capability. Therefore, this factor is not considered herein.

R&D factors (RD)

Research and development (R&D) activities can be considered the heart of innovation. R&D helps the firm to expand its existing technologies and to establish novel technologies or improved R&D function (Lu *et al.,* 2007). Romijn & Albaladejo (2002) mentioned that R&D expenditures and the number of scientists, engineers or R&D staff employed can be considered a positive internal factor for innovation capability. Wang *et al.* (2008) considered five R&D-related criteria for measuring innovation capability under uncertainty. Two of them, which are used in this study as well, are "percentage of researchers to overall employees" and "ratio of R&D expenditures to total number of employees". Sahan & Zhang (2009) used three R&D-related criteria, namely "The proportion of R&D staff", "The proportion of R&D expenditures" and "R&D success rate" for an enterprise's independent innovation capability.

This study considers four factors to measure R&D activities. All criteria values are calculated using the BIFPET algorithm except for the "Technology watching department" criterion. For companies and investors alike, technology watching systems trace technological developments around the world (Dereli & Durmusoglu, 2010) and make it possible to discover current trends in innovation. Dereli & Durmusoglu (2010) developed a trend-based patent alert system using patent data for setting a technology watch on industrial technologies. Daim *et al*. (2012) used patent alert system to crack current status of wind energy technology. The selection of research themes or the decisions related to R&D direction can be also done by using patent information (WIPO, 2003). Research themes and R&D policy affect a firm's innovation potential directly. Therefore, the presence of a technology watching department contributes positively to the innovation capability potential of the investment.

Past research related to innovation capability has used many factors, but consistently at least one of them is an R&D related factor. Details on R&D factor for innovation capability can be found in Guan & Ma (2003), Korkmaz *et al.* (2009), Martinez-Roman *et al.* (2001) and Tang & Li, (2010). The calculation of factors considered is given in the following formulas:

1) Rate of total R&D expenditure in each year (RD_1) = Annual R&D expenditure (RD_{11}) / HR_{42}
2) The presence of a Technology watching department (RD_2) is equal to 1 if the firm has this department and 0 otherwise.
3) Percentage of total full-time or part-time R&D personnel in the company (RD_3) = Total full-time or part-time R&D personnel in the company (RD_{31}) / HR_{12}
4) Per capita computers (RD_4) = Total number of computers (RD_{41}) / HR_{12}

Miscellaneous factors (MS)

Factors affecting innovation capability apart from those already mentioned are given in this section. Formulas of considered factors are given in the following.

1) The presence of a web site, where the firm can gather expectations and perceptions from customers (MS_1), is equal to 1 if firm has such a website and 0 otherwise.
2) Fraction of the employees who work in marketing (MS_2) = The number of employees who work in marketing (MS_{21}) / HR_{12}
3) Fraction of spending dedicated to marketing (MS_3) = Expected annual expenditure for marketing (MS_{31}) / HR_{42}
4) Number of universities or research centers in the region (MS_4):

$$MS_4 = \begin{cases} 0{,}2, \text{ if there is one university or research center} \\ 0{,}4, \text{ if there are two universities or research centers} \\ 0{,}6, \text{ if there are three universities or research centers} \\ 0{,}8, \text{ if there are four universities or research centers} \\ 1, \text{ if there are five or more universities or research centers} \end{cases}$$

It should be noted that some factors, such as the number of new products, the rate of return on new products in total sales, the maximum output of products per year, sales revenue of new products, and the fraction of total revenue created by new products are not considered to predict innovation capability. Because, these factors are output related factors for innovation capability.

Belief in fuzzy probability estimations of time (BIFPET) algorithm

The BIFPET algorithm was proposed by Shipley *at al.* (1996). The application of the BIFPET algorithm in the literature is quite limited. After their introduction of BIFPET algorithm to literature, Shipley *et al*. (1997) extended BIFPET algorithm by assigning an upper and lower approximation of each predicted activity value to address model uncertainty in the decision-making process. Sanal (2000) modified the BIFPET algorithm for the application of scheduling problem. Then, Shipley & Stading (2012) applied a BIFPET-based algorithm to the problem of supplier selection.

Prediction of innovation capability is not easy task due to the fact that there is no perfect consensus about either the logic behind, or a framework for effective innovation. The idea of using multi-level input contributors is to obtain the necessary information correctly in the calculation process. This provides multiple options to predict the innovation capability of an investment project. Evaluation of investment projects with respect to innovation capability level needs to consider multi-level input contributors such as expert, investor and decision-makers. Furthermore, there are multi criteria affecting innovation capability level of investment projects. Therefore, it is necessary to use multi-level input contributors to predict innovation capability correctly in the proposed framework. The major contribution of the BIFPET algorithm is to take "opinions of experts, investors and decision makers together" into account in the calculation process for the prediction of innovation capability of investment projects. Therefore, the BIFPET algorithm provides the prediction of innovation capability of investment projects through multiple perspectives. It also assures an opportunity to model innovation under vagueness. To investors and governments, this paper presents a novel approach for the prediction of innovation capability as well as a real-life case study on the successful application of the BIFPET algorithm.

Figure 2 presents the main logic behind this study. It shows the flow of information within the BIFPET algorithm and proposed framework for the prediction of innovation capability potential of an investment project. The steps of the BIFPET algorithm are given based on Shipley *et al*. (1996) as follows:

1) For each factor, A_i (i= 1,2,…,m), t_{ki} (k=1, 2, 3) is defined as optimistic (t_{1i}), most possible or (t_{2i}), pessimistic (t_{3i}) (t_{1i}, t_{2i}, t_{3i} is assigned by a supervisor). Each activity value, t_{Ai}, is given by the equation:

$t_{Ai} = \sum_{k} \tau_{ki} / t_{ki}$ for all A_i where τ_{ki}=1.

2) Fuzzy probability, Q_{Aik} is then defined for each A_i in terms of each t_{ki} as follows:

$Q_{Aik} = \sum_{j} \alpha_{kij} / a_{kij}$ for all t_{ki} ,

where a_{kij} is assigned by the supervisor and uses the applicable probability value assigned to t_{1i}, t_{2i}, t_{3i}. α_{kij}, is assigned by the manager, shows belief in the probability a_{kij}.

3) All a_{kij} satisfying the $\sum_{k \in H} a_{kij_k} = 1$ condition for set H of each k should be considered. For each a_{kij}=0 for $k \notin H$.

4) Calculate b_{il} value as follows:

$$b_{il} = \begin{cases} \sum_{k} a_{kij_k} t_{ki} & \text{if } \sum_{k} a_{kij_k} = 1 \\ 0 & \text{otherwise} \end{cases}$$

where p = a distinct number: if $\sum_{k} a_{kij_k} = 1$, 1 = a Determine $c_{il} = \min\{\tau_{ki}, \alpha_{kij}\}$ for all satisfied $\alpha_{kij} \neq 0$ condition. Herein, c_{il} shows the degree of belief that expected value is b_{il}.

5) Compute $E(t_{Ai})$ to defuzzification as follows:

$E(t_{Ai}) = \sum_{l} c_{il} b_{il} / \sum_{l} c_{il}$

As can be seen from Figure 2, the input values for the BIFPET algorithm is obtained from decision makers and an expert. The decision makers assign three important values, namely; 'optimistic', 'pessimistic' and 'most possible' value for the criteria. In addition, the decision makers determine probability values for each value as well. The expert then evaluates the values determined by the decision makers and assign 'belief values' based on his/her perception. Basically, the expert can consider achievement and growth performance of the factory, if the investment is 'expansion type' and the backgrounds of the decision makers are related to the investment area. The BIFPET algorithm uses the values obtained from the decision makers and the expert to find the expected value of the factors in the future. Finally, the investor predicts the importance of the each factor with respect to his/her investment by assigning a value called "weight" as shown in the Figure 2. The proposed framework calculates an index value, which shows 'innovation capability level' of the investment project in the future, by using factor' weight and the result of the BIFPET algorithm.

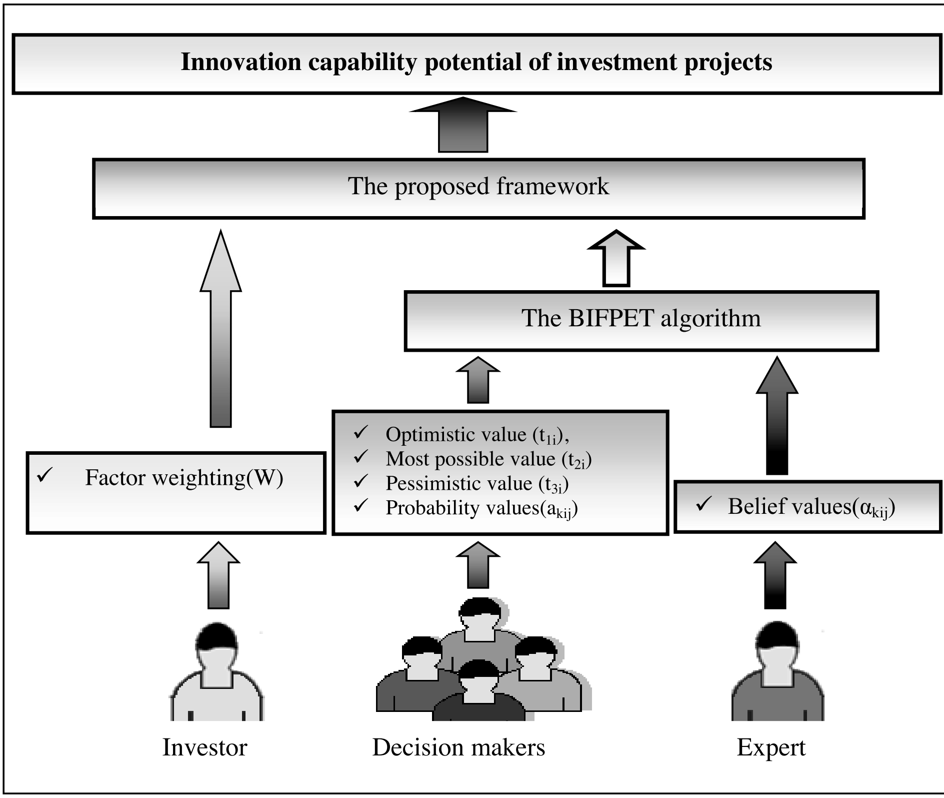

Fig. 2. Flow of information within the BIFPET algorithm and proposed framework

CASE STUDY FOR CARPET INDUSTRY

In this section, we show the prediction of the innovation capability of a real investment project by using proposed framework with the BIFBET algorithm. In this case study, the investor considers investing in a factory in Gaziantep, Turkey that has manufactured different qualities and types of carpet since 1997. The city of Gaziantep in Turkey is a center of carpet production. The factory exports all of the produced carpet to other countries. The investor wants to transfer the factory to a new area in Gaziantep called the Fifth Gaziantep Industrial Zone, due to factory growth. Therefore, this investment project can be considered as an expansion investment as well. There are two other decision makers involved in investment assessment. One is the son of the investor and the other is the investor's associate, who has 20 years' experience in the carpet industry. These two people directly affect the investor's decisions related to this investment opportunity.

The use of innovation surveys has been increased in recent years in the literature (Maravelakis *et al*., 2006). Herein, two surveys are conducted for the prediction of innovation capability potential of the investment project described in the case study. The first survey is completed by the investor to determine the weights of the various innovation factors, while the second survey is completed by the two decision makers to determine the factor values assigned (O), (Po) and (Pe) and related probability values. The investor considered the importance of the each factor for the textile sector, especially for carpet production and discussed them himself during the execution of the survey. On the other hand, two decision makers who affect the investor try to determine the values of the factors, using (O), (Po) and (Pe) value, in the future and assign the probability value of each predicted value based on their experiences and the current condition of the factory during the execution of the survey. In addition to these two surveys, we assign a belief value for each of the assigned (O), (Po) and (Pe) value by considering the achievement and growth performance of the factory so far and in addition, the backgrounds of the decision makers with respect to questions asked and the reasons for answers given to questions. Table 2 shows the factor weights assigned by the investor, while Table 3 reports (O), (Po) and (Pe) values and related probability values determined by the decision makers, as well as belief values determined by us. Figure 3 clarifies the meaning of the numbers in Table 3. In addition, Table 4 shows the results obtained from the BIFPET algorithm for prediction, while Table 5 gives both the result of the predicated innovation capability potential of the investment project and the results of the factors and sub-factors included in proposed framework.

It should be noted that RD_2 and MS_1 are measured by "yes" or "no" type of survey questions and the values for these factor are assigned automatically belong to the answer given by decision makers (see the definition of RD_{21} and MS_1). Herein, the investor does not want to establish a technology watching department (RD_2), while he does want to establish a website to gain expectations and perceptions from customers (MS_1). Therefore, the value of RD_2 and MS_1 are 0 and 1, respectively. In addition, MS_4 is assigned a value of 0.6 based on the number of universities or research centers in city of Gaziantep (see the definition of MS_4). Furthermore, the investor will invest in a new carpet factory. Therefore, 0.4 is assigned to the value of TR_1 and TR_2 because the investment in textile industry can be considered as investment in materials technology (see the definition of TR_1 and TR_2). Lastly, the values of HR_3, HR_{11}, HR_{12}, HR_{21}, HR_{DR}, HR_{GR}, HR_{UG}, HR_{51}, HR_{52}, HR_{61}, FF_2, RD_{31}, RD_{41} and MS_{21} are rounded up to the nearest integer due to the non-acceptance of decimal numbers for these factors.

Table 2. Factor weights

NO	FACTORS	WEIGHT	NO	SUB-FACTORS FOR *HR*	WEIGHT	NO	SUB-FACTORS FOR *RD*	WEIGHT
1	W_{HR}	0.30	1	HR_1	0.10	1	RD_1	0.15
2	W_{TR}	0.10	2	HR_2	0.30	2	RD_2	0.15
3	W_{FF}	0.25	3	HR_3	0.05	3	RD_3	0.15
4	W_{RD}	0.30	4	HR_4	0.02	4	RD_4	0.55
5	W_{MS}	0.05	5	HR_5	0.30		TOTAL	1
	TOTAL	1	6	HR_6	0.23			
				TOTAL	1			
NO	**SUB-FACTORS FOR *TR***	**WEIGHT**	**NO**	**SUB-FACTORS FOR *FF***	**WEIGHT**	**NO**	**SUB-FACTORS FOR *MS***	**WEIGHT**
1	TR_1	0.90	1	FF_1	0.50	1	MS_1	0.40
2	TR_2	0.10	2	FF_2	0.50	2	MS_2	0.20
	TOTAL	1		TOTAL	1	3	MS_3	0.30
						4	MS_4	0.10
							TOTAL	1

Table 4. The results obtained from BIFPET algorithm

Factor	Result	Factor	Result	Factor	Result
HR_{11}	2	HR_{41}	8100	RD_{11}	754.78
HR_{12}	58	HR_{42}	3569473	RD_{31}	1
HR_{21}	7	HR_{51}	1	RD_{41}	16
HR_{DR}	1	HR_{52}	4	MS_{21}	6
HR_{GR}	4	HR_{61}	16	MS_{31}	6249.09
HR_{UG}	6	FF_2	1		

Table 3. Estimated values

Factor	(t1i, t2i, t3i)	Value	Q_{Aik}	Factor	(t1i, t2i, t3i)	Value	Q_{Aik}
HR_{11}	Optimistic	1	0.6/0.3 + 0.5/0.25	HR_{52}	Optimistic	3	0.8/0.4 + 0.6/0.35
	Most possible	2	0.9/0.5 + 0.6/0.45		Most possible	4	0.5/0.1 + 0.6/0.4
	Pessimistic	3	0.6/0.2 + 0.4/0.3		Pessimistic	5	0.9/0.5 + 0.5/0.25
HR_{12}	Optimistic	50	0.7/0.4 + 0.7/0.5	HR_{61}	Optimistic	10	0.9/0.1 + 0.8/0.4
	Most possible	60	0.8/0.4 + 0.3/0.3		Most possible	15	0.5/0.4 + 0.5/0.2
	Pessimistic	70	0.8/0.2 + 0.2/0.2		Pessimistic	20	0.3/0.5 + 0.5/0.4
HR_{21}	Optimistic	4	0.9/0.4 + 0.5/0.25	FF_{2}	Optimistic	0	0.95/0.1 + 0.9/0.4
	Most possible	7	0.8/0.3 + 0.7/0.5		Most possible	1	0.3/0.8 + 0.15/0.4
	Pessimistic	8	0.8/0.3 + 0.4/0.25		Pessimistic	2	0.1/0.1 + 0.1/0.2
HR_{DR}	Optimistic	0	0.95/0.7 + 0.9/0.4	$^{*}RD_{11}$	Optimistic	0	0.9/0.8 + 0.8/0.7
	Most possible	1	0.2/0.2 + 0.1/0.4		Most possible	2.800	0.3/0.1 + 0.35/0.2
	Pessimistic	2	0.05/0.1 +0.05/0.2		Pessimistic	4.200	0.2/0.1 + 0.2/0.1
HR_{GR}	Optimistic	3	0.7/0.3 + 0.6/0.5	RD_{31}	Optimistic	0	0.9/0.9 +0.85/0.85
	Most possible	4	0.9/0.5 + 0.2/0.3		Most possible	1	0.5/0.05 + 0.2/0.1
	Pessimistic	5	0.5/0.2 + 0.1/0.2		Pessimistic	2	0.5/0.05 +0.1/0.05
HR_{UG}	Optimistic	5	0.9/0.7 + 0.55/0.6	RD_{41}	Optimistic	10	0.5/0.3 + 0.5/0.2
	Most possible	6	0.8/0.2 + 0.4/0.3		Most possible	15	0.5/0.3 + 0.6/0.6
	Pessimistic	7	0.4/0.1 + 0.4/0.1		Pessimistic	20	0.5/0.4 + 0.4/0.2
$^{*}HR_{41}$	Optimistic	6.000	0.8/0.4 + 0.8/0.4	MS_{21}	Optimistic	4	0.8/0.1 + 0.7/0.3
	Most possible	9.000	0.9/0.5 + 0.9/0.5		Most possible	5	0.9/0.3 + 0.8/0.4
	Pessimistic	12.000	0.8/0.1 + 0.9/0.1		Pessimistic	6	0.7/0.6 + 0.7/0.3
$^{*}HR_{42}$	Optimistic	2.777.800	0.7/0.4 + 0.9/0.5	$^{*}MS_{31}$	Optimistic	6.000	0.8/0.3 + 0.8/0.5
	Most possible	4.166.700	0.9/0.5 + 0.8/0.35		Most possible	6.200	0.6/0.4 + 0.7/0.3
	Pessimistic	5.555.600	0.3/0.1 + 0.3/0.15		Pessimistic	6.700	0.7/0.3 + 0.5/0.2
HR_{51}	Optimistic	0	0.9/0.3 + 0.7/0.35				
	Most possible	1	0.8/0.5 + 0.7/0.4				
	Pessimistic	2	0.3/0.2 + 0.2/0.25				

*The value of the factor is measured by $.

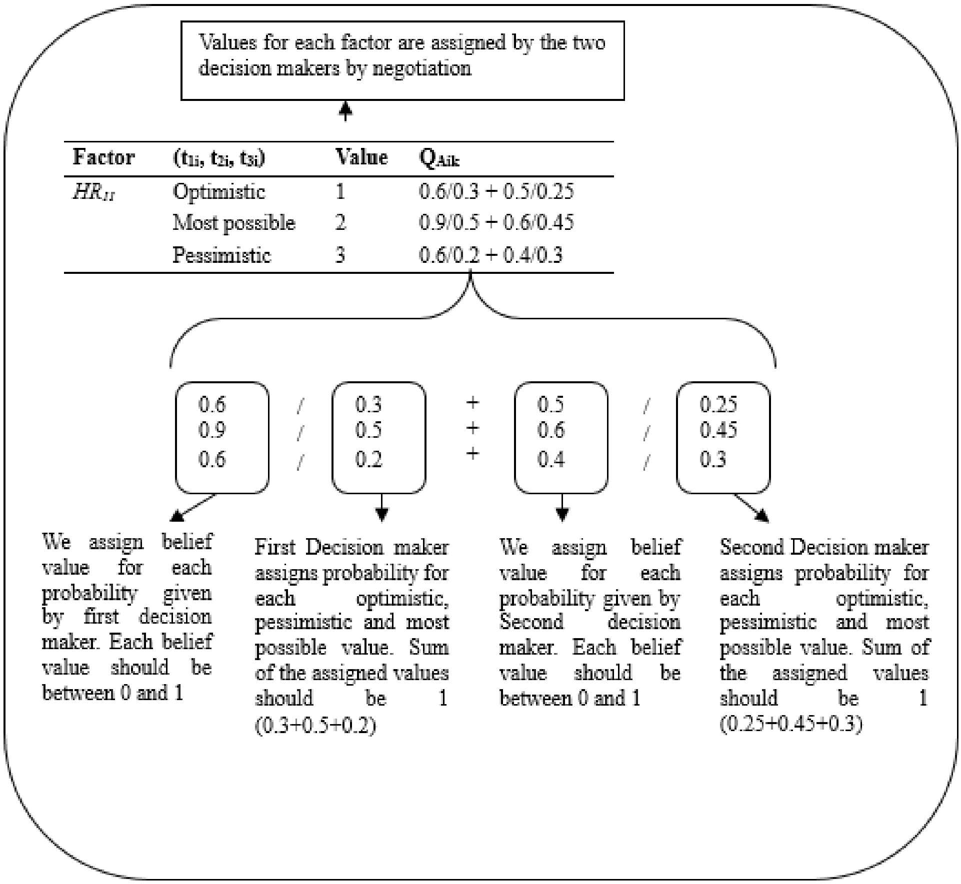

Fig. 3. An overview of Table 2

To show the calculation process of the BIFPET algorithm for prediction of innovation capability, RD_{41} is predicted as follows:

Herein, we can continue from step 3 in the BIFPET algorithm because first two steps include input data collations given in Table 3. There are three possible combinations that sum to one according to Step 3. These are:

Q_{A1k} is defined first for RD_{51}

$a_{11} + a_{21} + a_{31} = 0.3 + 0.3 + 0.4 = 1.00$

$a_{12} + a_{22} + a_{32} = 0.2 + 0.6 + 0.2 = 1.00$

$a_{22} + a_{31} = 0.0 + 0.6 + 0.4 = 1.00$

Calculations of b_{il} for each of defined Q_{A1k} are required in Step 4. These calculations are:

$b_{11} = (0.3) * (10) + (0.3) * (15) + (0.4) * (20) = 15.5$

$b_{12} = (0.2) * (10) + (0.6) * (15) + (0.2) * (20) = 15$

$b_{13} = (0.0) * (10) + (0.6) * (15) + (0.4) * (20) = 17$

According to Step 5, the degree of belief assigned by the expert for RD_{51} is assessed as follows.

$c_{11} = \min \{0.5, 1; 0.5, 1; 0.5, 1\} = 0.5$

$c_{11} = \min \{0.5, 1; 0.6, 1; 0.4, 1\} = 0.4$

$c_{11} = \min \{0.5, 1; 0.6, 1; 0.5, 1\} = 0.5$

It should be noticed that the last defined Q_{A1k} value for RD_{51} is (0.6, 0.4). However, according to Shipley *at al*. (1996), it becomes (0.0, 0.6, 0.4) with the addition of the zero. Similarly, belief value of this three-tuple becomes (0.5, 0.6, 0.5) with the addition of the smallest value of belief among the three-tuple (0.5).

Now, we defuzzify the expected value by using formula given in Step 6 such that:

$E(RD_{41}) = [(0.5 \times 15.5) + (0.4 \times 15) + (0.5 \times 17)] / (0.5 + 0.4 + 0.5) =$ ***15.89***.

This value shows the total number of computer. Therefore, it is rounded up to the nearest integer as ***16***.

The aim of this paper is to propose a new framework for ranking the innovation capability of investment projects. The proposed framework finds an index value that shows the relative innovation capability potential of the investment in the future. The result for the case study makes it appear that innovation capability of that investment is quite low. However, this must be judged, relative to another investment opportunity or relative to a personal threshold for innovation, which is subjectively determined. The method gives the sense that innovation capability for the case study firm is low is no surprise. The decision makers predict that just one R&D employee (RD_{31}) will work in their company in the future. In addition to this, the remaining factors' value is also not impressive. The innovation capability potential of a different investment project can also be easily found and can be prioritized against this investment project using the proposed framework. Governments, entrepreneurs and institutions can select a most suitable applicant project among the prioritized alternatives based on each project's index value.

Table 5. The resulting comparative innovation capability potential

NO	FACTORS	RESULT	NO	SUB FACTORS	RESULT	NO	SUB FACTORS	RESULT
1	HR	0.1815971	1	HR_1	0.0034483	11	RD_1	0.0000317
2	TR	0.4000000	2	HR_2	0.0362069	12	RD_2	0.0000000
3	FF	0.2000000	3	HR_3	0.0034483	13	RD_3	0.0025862
4	RD	0.0026204	4	HR_4	0.0000454	14	RD_4	0.0000025
5	MS	0.4812149	5	HR_5	0.0750000	15	MS_1	0.4000000
			6	HR_6	0.0634483	16	MS_2	0.0206897
			7	TR_1	0.3600000	17	MS_3	0.0005252
			8	TR_2	0.0400000	18	MS_4	0.0600000
			9	FF_1	0.2000000		***IC =0.1693260***	
			10	FF_2	0			

CONCLUSIONS

In this study, we introduced a framework for the prediction of comparative innovation capability potentials to rank investment projects. There is no other known study that proposes a framework for the prediction of innovation capability potential of investment projects in literature. Therefore, to best of the authors' knowledge, this is the first attempt that proposes a framework for such a prediction. Knowing the innovation capability potential of investment projects provides many benefits and significant advance clues for governments and entrepreneurs, because this method makes it possible to know the relative futures of investments projects with respect to innovation before the investment. Also, many investors apply to a government to take advantage of incentives. Therefore, the decision of whether to support the investor for his/her investment can be more prudently made by the funding agency using this proposed method, as investment projects can be ordered with respect to their innovation capability potential.

In future work, the extension of BIFPET methodology proposed by Shipley *et al.* (1997) might be adapted for this purpose, instead of the simpler original BIFPET methodology. There may be an opportunity to ask more than one expert to assign belief values for some investments. Therefore, the proposed solution should be extended in case of multiple experts. In addition, any one of the weighting methods such as SAW, AHP and ANP can be used for weighting the factors and sub-factors for future studies. A larger (and longer) study is needed to test the innovation capability scores and rankings against empirical innovation outcomes of actual companies, so as to verify the intended predictive power of this fuzzy methodology. More than one case study can also be conducted to sort the investment alternatives in descending order with respect to innovation capability.

REFERENCES

Alam, S.S. 2011. Entrepreneur's traits and firm innovation capability: an empirical study in Malaysia. Asian Journal of Technology Innovation, **19**(1): 53-66.

Altuntas, S. & Dereli, T. 2012. An evaluation index system for prediction of technology commercialization of investment projects. Journal of Intelligent & Fuzzy Systems, **23**(6): 327-343.

Assink, M. 2006. Inhibitors of disruptive innovation capability: a conceptual model. European Journal of Innovation Management, **9**(2): 215-233.

Akman, G. & Yılmaz, C. 2008. Innovative capability, innovation strategy and market orientation: an empirical analysis in Turkish software industry. International Journal of Innovation Management, **12**(1):69-111.

Atanasiu, D. Lincaru, C. & Ciucă, V. 2009. The innovation potential and the innovation impact in Romanian firms. In Proc 3 rd Central European Conference in Regional Science- CERS, 234-245.

Baldwin, J.R. & Johnson, J. 1996. Business strategies in more- and less-innovative firms in Canada. Research Policy, **25**(5):785–804.

Calantone, R.J., Cavusgil, S.T. & Zhao, Y. 2002. Learning orientation, firm innovation capability, and firm performance. Industrial Marketing Management, **31**(6):515– 524.

Cavusgil, S.T., Calantone, R.J. & Zhao, Y. 2003. Tacit knowledge transfer and firm innovation capability. Journal of Business & Industrial Marketing, **18**(1):6-21.

Chen, T.J. & Chen, J. 2006. Determinants of innovation capability in small and medium enterprises: an empirical analysis from China. In Proc International Engineering Management Conference, 283 – 286.

Chen, L. & Xu, Q. 2009. The mechanism of innovation capability leveraging via strategy in SMEs. In Proc International Conference on Industrial Engineering and Engineering Management IEEM, 1057-1061.

Chen, M.H. & Yang, Y.J. 2009. Typology and performance of new ventures in Taiwan. A model based on opportunity recognition and entrepreneurial creativity. International Journal of Entrepreneurial Behaviour & Research, **15**(5): 398-414.

Damanpour, F. & Wischnevsky, J.D. 2006. Research on innovation in organizations: Distinguishing innovation-generating from innovation-adopting organizations. Journal of Engineering and Technology Management, **23**(4): 269-291.

Daim, T. Iskin, I. Li, X. Zielsdorff, C. Bayraktaroglu, A.E. Dereli, T. & Durmusoglu, A. 2012. Patent analysis of wind energy technology using the patent alert system. Word Patent Information **34**(1): 37-47.

Dereli, T. & Durmusoglu, A. 2010. Application of Possibilistic Fuzzy Regression for Technology Watch. Journal of Intelligent and Fuzzy Systems, **21**(5):353-363.

Dereli, T. Durmusoglu A. & Daim, T.U. 2011. Buyer/seller collaboration through measurement of beliefs on innovativeness of products. Computers in Industry **62**(2):205-212.

ERIA. Economic Research Institute for ASEAN and East Asia. 2010. How to enhance innovation capability with internal and external sources. Edited by Paterapong Intarakumnerd. Research Project Report.

Elmquist, M. & Masson, P.L. 2009. The value of a 'failed' R&D project: an emerging evaluation framework for building innovative capabilities. R&D Management **39**(2): 136-152.

Guan, J. & Ma, N. 2003. Innovative capability and export performance of Chinese firms. Technovation **23**(9) 737-747.

Guan, J.C., Yam, R.C.M., Mok, C.K. & Ma, N. 2006. A study of the relationship between competitiveness and technological innovation capability based on DEA models. European Journal of Operational Research, **170**(3) 971–986.

Kaufman, A., Wood, C.H. & Theyel, G. 2000. Collaboration and technology linkages: a strategic supplier typology. Strategic Management Journal, **21**(6):649–663.

Kittilaksanawong, W. & Ren, Z. 2013. Innovation capability building through intermediary organizations: cases of manufacturing small- and medium-sized enterprises from China's Zhejiang province. Asian Journal of Technology Innovation, **21**(2): 62-79.

Koc, T. & Ceylan, C. 2007. Factors impacting the innovative capacity in large-scale companies. Technovation, **27**(3): 105-114.

Koc, T. 2007. Organizational Determinants of Innovation Capacity in Software Companies. Computers & Industrial Engineering, **53**(3):373–385.

Kusiak, A. 2009. Innovation: A data-driven approach. International Journal of Production Economics **122**(1):440-448.

Korkmaz, S., Ermeç, A. & Yücedağ, N. 2009. Firms innovation capabilities and their effects on export performances. Anadolu University Journal of Social Sciences, **9**(2):83-104.

Laakso, S.K., Pihkala, T., Kraus, S. 2012. Facilitating SME Innovation Capability through Business Networking. Creativity and Innovation Management, **21**(1):93-105.

Lawson, B. & Samson, D. 2001. Developing innovation capability in organizations: A dynamic capabilities approach. International Journal of Innovation Management, **5**(3):377–400.

Lixia 2010. Research on Scale and Technology Innovation Capability of Listed Automobile Enterprise. International conference on computational intelligence and software engineering. 10-12 Dec., 1-4. Wuhan.

Lin, H.F. 2007. Knowledge sharing and firm innovation capability: an empirical study. International Journal of Manpower, **28**(3/4):315 – 332.

Lu, L.Y., Chen, C.B. & Wang, C.H. 2007. Fuzzy multi attribute analysis for evaluating firm technological innovation capability. International Journal of Technology Management, **40**(1-3):114-130.

Myers, D.D. 1984. Technological innovation and entrepreneurship from the human side. Engineering management International, **2**(4):229-234.

Maravelakis, E., Bilalis, N., Antoniadis, A., Jones, K.A. & Moustakis, V. 2006. Measuring and benchmarking the innovativeness of SMEs: A three-dimensional fuzzy logic approach. Production Planning & Control, **17**(3):283-292.

Marques, C.S. & Ferreira, J. 2009. SME Innovative Capacity, Competitive Advantage and Performance in a 'Traditional' Industrial Region of Portugal. Journal of Technology Management & Innovation, **4**(4):53-68.

Martínez-Román, J.A., Gamero, J. & Tamayo, J.A. 2011. Analysis of innovation in SMEs using an innovative capability-based non-linear model: A study in the province of Seville Spain. Technovation **31**(9):459–475.

Nassimbeni, G. 2001. Technology, innovation capacity, and the export attitude of small manufacturing firms: a logit/tobit model. Research Policy, **30**(2): 245–262.

Numprasertchai, S., Kanchanasanpetch, P. & Numprasertchai, H. 2009. Knowledge creation and innovation capability in the public university. International Journal of Innovation and Learning, **6**(5):568-580.

Ngo, L.V. & O'Class, A. 2012. In Search of Innovation and Customer-related Performance Superiority: The Role of Market Orientation, Marketing Capability, and Innovation Capability Interactions. Journal of Product Innovation Management, **29**(5): 861-877.

OECD. Organisation for Economic Co-operation and Development. 1988, New Technologies in the 1990s A Socio-economic Strategy. Report of Group of Experts on the Social Aspects of New Technologies. Paris.

Perez-Cano, C. 2013. Firms size and appropriability of the results of innovation. Journal of Engineering and Technology Management, **30**(3): 209-226.

Poon, J.P.H., & MacPherson, A. 2005. Innovation strategies of Asian firms in the United States, Journal of Engineering and Technology Management, **22**(4): 255-273.

Romijn, H. & Albaladejo, M. 2002. Determinants of innovation capability in small electronics and software firms in southeast England. Research Policy, **31**(7): 1053-1067.

Rampersad, G., Plewa, C. & Troshani, I. 2012. Investigating the use of information technology in managing innovation: A case study a university technology transfer office. Journal of Engineering and Technology Management, **29**(1): 3-21.

Shan, W. & Zhang, O. 2009. Extension theory and its application in evaluation of independent innovation capability. Kybernetes **38**(3/4):457-467.

Shipley, M.F., Korvin, A.D. & Omer, K. 1996. A Fuzzy Logic Approach for Determining Expected Values: A Project Management Application. The Journal of the Operational Research Society, **47**(4):562-569.

Shipley, M.F., Korvin, A.D. & Omer, K. 1997. BIFPET methodology versus PERT in project management: fuzzy probability instead of the beta distribution. Journal of Engineering and Technology Management, **14**(1):49–65.

Shipley, M.F. & Stading, G.L. 2012. Supplier Selection Decisions: A Fuzzy Logic Model Based on Quality Aspects of Delivery. Advances in Computational Intelligence, Communications in Computer and Information Science, 300, 1-9.

Subramaniam, M. & Youndt, M.A. 2005. The influence of intellectual capital on the types of innovative capabilities. Academy of Management Journal, **48**(3):450-463.

Sun, H. 2009. A meta-analysis on the influence of national culture on innovation capability. International Journal of Entrepreneurship and Innovation Management, **10**(¾): 353–360.

Sanal, U.Z. 2000. A Decision Support System for Fuzzy Scheduling of Soft-ware Projects.In: Autotestcon Proceedings. 263–272.

Sher, P.J. & Yang, P.Y. 2005. The effects of innovative capabilities and R&D clustering on firm performance: the evidence of Taiwan's semiconductor industry. Technovation **25**(1): 33-43.

Sun, H., Wong, S.Y., Zhao, Y. & Yam, R. 2012. A systematic model for assessing innovation competence of Hong Kong/China manufacturing companies: A case study. Journal of Engineering and Technology Management, **29**(4):546-565.

Tang, W. & Li, F. 2010. Research of Innovation capability comprehensive evaluation based on factor analysis and DEA model.in Proc International Conference on Information Management, Innovation Management and Industrial Engineering ICIII, 639-642.

Taskin, H., Adali, M.R. & Ersin, E. 2004. Technological intelligence and competitive strategies: An application study with fuzzy logic. Journal of Intelligent Manufacturing, **15**(4):4417-429.

Tasmin, R. & Woods, P. 2007. Relationship between corporate knowledge management and the firm's innovation capability. International Journal of Services Technology and Management, **8**(1):62–79.

Terziovski, M. 2007. Building Innovation Capability in Organizations: An International Cross-case Perspective. Imperial College Press, London.

Tsenga, M.L., Linb, Y.H. Limc, M.K. & Teehankee, B.L. 2015. Using a hybrid method to evaluate service innovation in the hotel industry. Applied Soft Computing, **28**:411–421.

Ural, T. & Acaravci, S.K. 2012. Role of innovation capability and appropriability regime in internationalization: empirical evidence from Turkish firms. Actual Problems of Economics, **128**(2): 439-449.

Wang, C.H., Lu, I.Y. & Chen, C.B. 2008. Evaluating firm technological innovation capability under uncertainty. Technovation **28**(6): 349-363.

Wonglimpiyarat, J. 2010. Innovation index and the innovative capacity of nations. Futures **42**(3):247–253.

Xu, Z., Lin, J. & Lin, D. 2008. Networking and innovation in SMEs: evidence from Guangdong Province, China. Journal of Small Business and Enterprise Development, **15**(4):788-801.

Yang, J., Rui, M. & Wang, J. 2006. Enhancing the firm's innovation capability through knowledge management: a study of high technology firms in China. International Journal of Technology Management, **36**(4):305–317.

Yang, J. 2012. Innovation capability and corporate growth: An empirical investigation in China. Journal of Engineering and Technology Management, **29**(1):34-46.

Yang, C., Zhang, Q. & Ding, S. 2015. An evaluation method for innovation capability based on uncertain linguistic variables, Applied Mathematics and Computation, **256**(C):160–174.

Yilin, L., Desheng, L., Luxiu, Z. & Yuming, Z. 2010. Modeling technological innovation capability as an engine of growth: evidence from China's SMEs", In Proc International Conference on Management of Innovation and Technology ICMIT, 841-846.

Zhao, H., Tong, X., Wong, P.K. & Zhu, J. 2005. Types of technology sourcing and innovative capability: An exploratory study of Singapore manufacturing firms. Journal of High Technology Management Research, **16**(2): 209–224.

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