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EVALUATION OF COMMERCIAL POTENTIAL OF A NEW TECHNOLOGY AT THE EARLY STAGE OF DEVELOPMENT WITH FUZZY LOGIC

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Abstract

Commercial potential is the opportunity of commercialization of the candidate technology. Every new technology to reach market needs to thrive and prosper in a continuously changing and unpredictable business environment. Determination of commercial potential of a technology is a necessary prerequisite element for defining successful commercialization strategies. Commercial potential can be determined by various methods.

The focus of this paper is on developing of a Fuzzy system for measuring commercial potential of a candidate technology at the early stage of development before spend the time and effort, based on Strategic Technology Evaluation Program (STEP).

Based on STEP, for commercialization, every new technology needs a number of characteristics; these characteristics are broken into some dimensions and this dimensions to some indices.

For measurement of commercial potential we use "IF {Fuzzy antecedents} THEN {Fuzzy consequent}" rule. This system uses experts' knowledge and includes implementation of Fuzzy logic method and terminology.

The approach that is described here is simply a framework, which can be modified to fit different situations as appropriate.

Keyword: Commercial Potential, Commercialization, Model, Measurement, Fuzzy Logic, early stage technology, technology development project evaluation, probability of commercialization

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1. Introduction

Everyday several different ideas come to the mind of people but so many of these ideas, while intriguing and novel, are not quite practical because they often could not be reduced to practice; or they don't directly address a significant market need; or they could not be implemented in a cost effective manner or they just could not be implemented at all! (Siegel et al. 1995)

Commercial potential in literature means "the possibility of commercialization of candidate technology" and/or "likelihood of a successful commercialization". The determination of commercial potential of a technology is a necessary prerequisite element for defining successful commercialization strategies. There are numerous methodologies for making such a determination.

Usually to determine the commercial potential of a technology, the strengths and weaknesses, as well as opportunities and constraints related to its commercial utilization should be evaluated. Recently, several models have been developed to determine the commercial potential of a technology. These models assess several factors that are effective on successful commercialization of the technology. However the principle problem including the synthesis of individual aspects, quantifying them and calculating the overall commercial potential of the technology has remained unanswered (Kathleen 2003; Martyniuk 2002; Martyniuk et al 2003; Martino 1995; Triandis 1990)

In other words, what has not been covered yet in the previous research is a more proactive approach by which one can forecast the success rate of commercialization of the technology in the process of R&D. Such a forecasting model would enable one to figure out the best scenario for a given technology to be matched with a specific transferor and transferee. (Sohn et al. 2003)

This paper presents a method that aids to the decision makers to select those early stage technologies who have potential of successful transfer to marketplace. For a prediction of a specific combination, we suggest a methodology based on a committee of experts. Because of inherent ambiguous of commercial potential, present study uses fuzzy logic to measure and quantify commercial potential for a candidate technology for development.

This paper has been organized as follows: in section 2 literatures related to commercialization and commercial potential evaluation would be reviewed. After that, the Strategic Technology Evaluation Program (STEP) model developed at the University of Cincinnati will be discussed. Then, the design of Fuzzy system for measuring is discussed. At the next stage, in order to validating our model based on the empirical study, the model was applied for measuring commercial potential of a candidate technology in RIPI[1]. Finally we summarize our study results and suggest further study areas.

2. Background

2.1. Commercial Potential

Commercialization in this study means *"converting or moving "technology" into a profit making position"* and technology refers to know-how, techniques, patented or otherwise proprietary processes, materials, equipment, systems, etc [Siegel et al. 1995].

Commercialization is the process of moving a technology or innovative concept from the idea stage to the marketplace. In other words; technology commercialization commonly define as the process of creating a product that is suitable for a particular market at an affordable price that fulfills the demand of the market. But more useful definition with the most coverage on our target in this article is "the process for commercialization of technology from R&D sector and laboratories to industrial companies" that is more common between experts. So emphasize in this article is on the process from "laboratories to industry" or "laboratories to market " (8; Balachandra et al. 1997; Logar et al. 200; Ghazinoori, 2005).

The technology commercialization process is not a simple linear process, but rather is a complex process involving many actors in many capacities. The commercialization process requires skills such as: product development, market assessment, market strategies, finance, manufacturing, accounting and …etc (Kathleen 2003; Loftus et al. 1994; Peter 1999).

There are several barriers against commercialization of a technology. Barriers against the commercialization of a technology could arise at each stage of the idea to market process. They range from lack of information; insufficient human capabilities; political and economic barriers such as lack of capital, high transaction costs, lack of full cost pricing, and trade and policy barriers; institutional and structural barriers; lack of understanding of local needs; business limitations such as risk aversion in financial institutions; excessive and costly regulations; and inadequate environmental codes and standards. In addition, there may be also technology specific barriers.

While there appears to be no shortage of barriers to technology commercialization, discovering a method to enhance the process is a difficult task. It is widely accepted that for successful and sustainable technology commercialization, there must exist a multi-faceted enabling environment. This environment should include favorable macroeconomic conditions, the involvement of

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social organizations, national institutions for technology innovation, human and institutional capacities for selecting and managing technologies, national legal institutions that reduce risk and protect intellectual property rights, codes and standards research and technology development, and the means for addressing equity issues and respecting existing property rights.

The decision to commercialize a technology is often made by an organization or individual, often the developer(s) of the technology, without a complete understanding of the processes and requirements that will ensure success. (Kathleen 2003; Martyniuk 2002; Babcock 1991; Brown 1997; Jain et al 2003)

One way to overcome these problems is evaluation of new technology and assessing its commercial potential. Such evaluation should be initiated as early as possible. The early evaluation of new technologies allows those with more commercial potential to be further developed in ways that would enhance the chances of successful technology commercialization.

While a number of tools have been developed to address some of the individual aspects of successful technology commercialization, but more strategic and informed, comprehensive process is desirable. However the major problem consisting of the synthesis of individual aspects, quantifying them and calculating the overall commercial potential of the technology has remained unsolved (Kathleen 2003; Brown 1997; Chifos et al 1997; Weick et al 2003)

The early identification of new, emerging technologies with high commercial potential has a number of advantages. Early identification by laboratories and firms seeking to commercialize their technologies can assist them in deciding whether to continue developing a technology and expend the time and effort necessary to obtain intellectual property protection (e.g., a patent) for the technology. Early assessment can also be used to identify what types of businesses or industries may be interested in, or best suited for further developing or adopting the technology in question. In either case, early recognition of commercial potential of the technology represents an effective use of resources and may aid in increasing the number of new technologies that eventually establish a commercial presence [Martyniuk et al 2003; Chifos et al 1997].

2.2. Commercial Potential Evaluation Research

As technology develops in a speedy manner, its life cycle tends to be reduced faster and the importance of successful commercialization of developed technology is getting higher.

Recently, much investment has been committed to R&D in the area of technology. However, its commercialization rate is reported to be lower than expected. This would imply the waste of huge amount of money. To increase the efficiency of the investment in the R&D, it is essential to understand the commercialization process.

Studies on commercialization process and infrastructure mainly have dealt with defining the concept of commercialization or conceptualizing the commercialization process. Some other studies have analyzed the success factors for each stage of technology transfer. What most of these studies missed was a structural relationship among the factors related to the commercialization. (Sohn et al 2003)

Researchers disagree strongly on how an appropriate R&D project evaluation model should be constructed and how data should be assessed. (Balachandra et al 1997)

Some models are strictly empirical and are based on statistical analysis of the correlation between project characteristics and project success (*e.g.*, Cooper, 1981). Others have proposed evaluation models based on operations research principles (e.g., Souder, 1973). Both approaches have benefits as well as shortcomings. The former may suffer from vaguely measured variables and from the difficulty of combining both financial and non-financial variables on a common scale. The latter has been found to be too complex to be of much practical use. (Astebro 2004).

There has been a great deal of research on the determinants of commercial potential using various analytical approaches. The research falls into three perspectives: 1) research on factors leading to success (Cooper, 1984; Goldenberg *et al.*, 2001; Yoon and Lilien. 1985; Voss, 1985); 2) research on factors leading to failure (Hopkins, 1981); and 3) research on factors that separate success from failure (Abratt and Lombard, 1993; Cooper, 1979; Cooper, 1985; Maidique and Zirger, 1984; Yoon and Lilien, 1985). In general, these studies suggest normative strategies to enhance success or avoid failure and have provided considerable evidence that a great number of factors can influence the outcomes of new technology development projects. The factors studied describe various combinations of product characteristics, development processes, organizational characteristics, strategic and market characteristics. Reviews can be found in Balachandra and Friar (1997), Lilien and Yoon (1989) and Linton *et al.*, (2002).

In general, it is said that technology evaluation (e.g. including valuation and assessment) is not a science but an art. The reason may be attributable to the following factors. First, technology is neither visible nor tangible. It is frequently embodied in human knowledge or in physical assets and hence difficult to identify the exact contents and scope. Second, economic value of technology is affected by various non-technical factors and realized only after it is commercialized to the market. (Mard 2000a; Mard 2000b; Tipping et al 1995)

Third, evaluation of technology is a subjective activity. Evaluation of technology is very much like the evaluation of beauty that is framed in the eye of beholder (Boer 1999). Furthermore, technology is traded in a supplier's market and thus hard to reach balanced price through market mechanism. Indeed, there are a number of traps or pitfalls in evaluating technology that technology manager may encounter. (Boer et al. 1998)
As mentioned above, the determination of commercial potential of a technology is a necessary prerequisite element for defining successful commercialization strategies. There are numerous methods for making such a determination. Various evaluation methods, ranging from intuitive judgment to complex options models have been developed. (Black et al. 1973) Although individual methods may differ one another in terms of criterion and procedure, the results of technology evaluation is expressed in score, index, or monetary value. (Sohn et al. 2005)

Among them, scoring model has been widely used. Briefly, scoring model uses a number of factors and makes evaluator subjectively rate score for each factor. Then the overall score of the technology is computed by addition or multiplication of individual scores (Souder 1972).

Figure 1 below illustrates one such methodology.

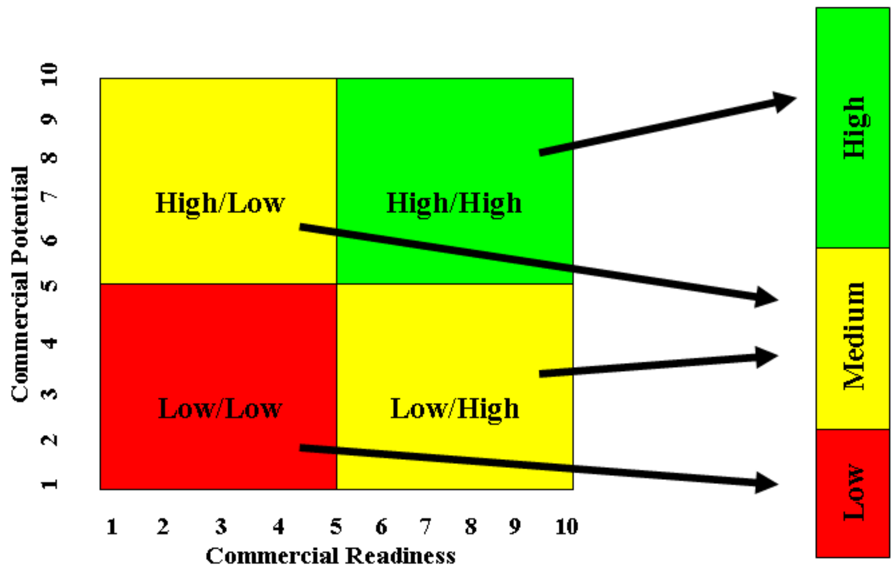

Figure 1. Commercialization Assessment Index

In this model the overall likelihood of a successful commercialization (i.e. commercial potential) is determined on a scale of 1 (low) to 10 (high). The likely time frame (commercial readiness) for this happening is also estimated on a scale of 1 (relatively long term, i.e. 5+ years) to 10 (short-term, i.e. a year or less).
As this approach illustrates an overall rating can be developed by combining these two factors. One way to determine the commercial potential is to evaluate strengths and weaknesses of "commercializable assets", as well as opportunities and constraints related to commercial utilization of these assets. (28)
However, the Commercialization Assessment Index is a scoring model for determination of commercial potential of technology but there are some limitations using this model including:
1. Scoring procedure hasn't detailed criteria
2. The model is blind to some aspects of commercial potential

In one study Astebro examined the impact of a comprehensive set of 36 innovations and product-market characteristics on the likelihood that an early stage NTD project will be commercialized.
These characteristics were including several dimensions of technological opportunity, competition, legal and societal conditions and twelve dimensions characterizing user need and market demand. Finally, four characteristics stand out as the most predictive ones; expected profitability, technological opportunity, development risk and appropriability conditions. These key variables predict future commercial success well with forward prediction accuracy of 80.9%. (Astebro 2004)

As Balachandra and Friar (1997) discusses, it is unlikely that there exists a single model of new technology development (NTD) project success that generalizes to all types of NTD projects. Rather, their suggestion is to develop various models for different classes of NTD projects and different decision-making situations to obtain better knowledge and predictive accuracy. (Balachandra et al. 1997)

In this study I therefore focus on the assessment of early stage NTD projects – the stage where minimal R&D funding has been expensed and the project can be considered only as an "idea" or "concept".
Therefore, In order to limit the scope and complexity of analysis, this study only examines the likelihood that a concept will reach to the market. This is an important intermediate stage for achieving financial returns and includes both technical success as well as acceptance in the marketplace.

3. Conceptual Model Discussion

There are many sources for evaluation of the new and emerging technologies. These evaluations may be single-focused with respect to technical feasibility or economic feasibility; or they may be multi-faceted, dealing with multiple aspects of a technology's fitness for commercial applications. In general, these evaluations fall into three general categories: market opportunity analyses (MOA), business plans, or more comprehensive evaluation methodologies such as the Strategic Technology Evaluation Program (STEP). Depending on the stage of development that the technology is in, one evaluation method may be preferable to another. STEP evaluates the commercial potential of technologies in different stages of development but this model is the most appropriate tool for evaluating new technologies at the early stages of technology development (Jain et al. 2003).

3.1. Strategic Technology Evaluation Program (STEP)

Over the last decade, the comprehensive Strategic Technology Evaluation Program (STEP) model has been developed and continuously modified to evaluate the commercial potential of emerging technologies. Versions of the model have been tested on over 100 technologies and in comparison with other methods, proved to be the most comprehensive developed tool (Jain et al. 2003; Chifos et al. 1997).

Evaluation criteria

The STEP method as employed at the University of Cincinnati was developed based upon deciding what questions the evaluators felt needed to be answered in order to effectively assess the new technology. The questions generally fell into six separate categories; economic aspects, market aspects, people aspects, process aspects, technical aspects and unique aspects. The STEP methodology was thus formulated as a synthesis of six evaluations: the technology evaluation, the process evaluation, the economic evaluation, the market evaluation, the perception evaluation and the regulatory/policy evaluation. The STEP process is graphically represented in Figure 2. Criteria for each evaluation are discussed below (Jain et al. 2003).

Technology evaluation

These basic technical attributes of a technology are the foundation for potential successful applications. Of interest in determining the commercial potential of a technology is the value of these technical attributes. Their value is based on the monetary potential of the application, as well as the uniqueness of the technical configuration. Further, the value may change depending on the level of a technology's protection by patents or licenses.
The purpose of the technical evaluation is to determine how the technology works and if it is capable of accomplishing its goal. In this section, one would ask: Is the technology capable of achieving the desired result? How does the technology work? How complex is it? What are the principles or concepts involved in this treatment? Are there any limiting factors, which influence the effectiveness of the technology?

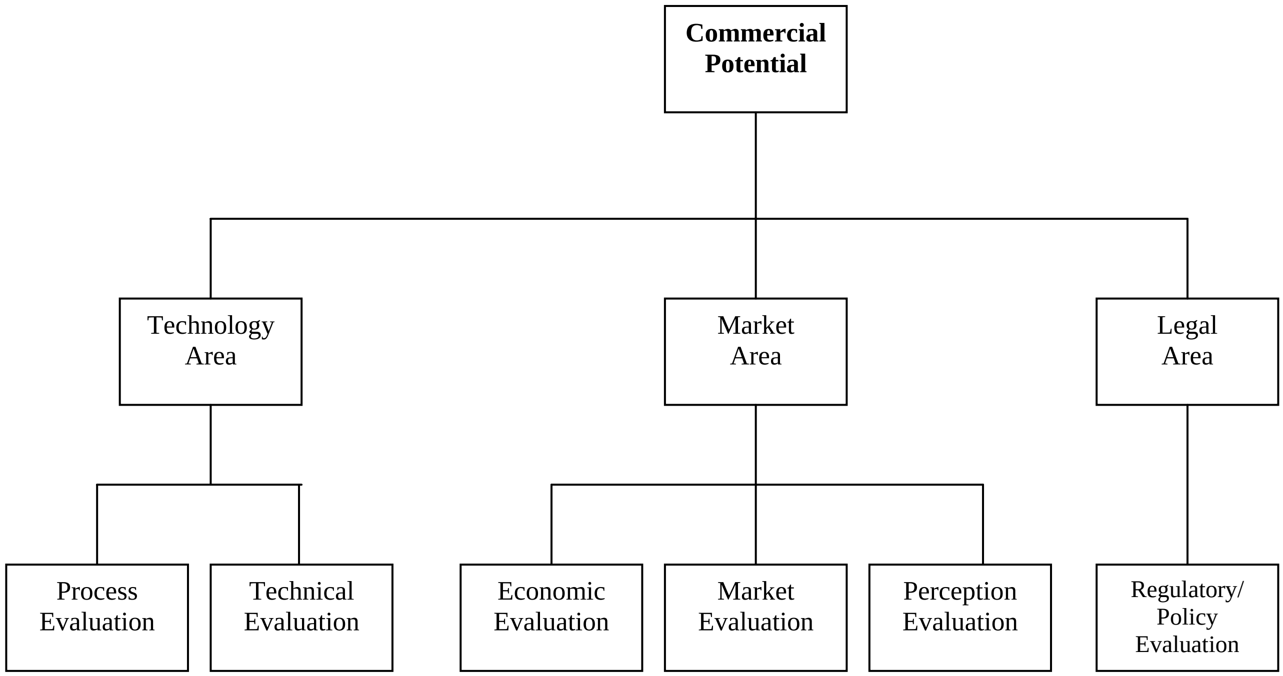

Figure 2. The STEP process

Process evaluation

The process aspects of the evaluation address the adoptability and adaptability of a new technology into existing methods of utilization or the process that a technology is going to replace. The changes that must be made for a technology to be adaptable or adoptable may require more than just the obvious costs of start up. A market evaluation should consider whether the new process may be what is referred to as a disruptive technology. A disruptive technology is one which changes the whole framework of a market, possibly completely eliminting other competing technologies, or creating a whole new technology field/niche. Additionally, the process evaluation should determine whether or not the technology can be adopted on a small scale before investing in major overhauls of existing processes. Another issue that needs to be explored in the process evaluation is whether the bulk of the potential market actually possesses the technical capability to integrate this new technology into their operations.

Economic evaluation

Economic aspects of a technology are evaluated by completing an examination of the costs and benefits that will be incurred by finishing the development and testing of the technology. Also other considerations are the costs of implementing the technology (for example any process changes) and the costs of operation and maintenance. In the early phases of a technology's development, estimating the monetary value of costs and benefits can be quite challenging. However, an estimation of the types of cost and the magnitude of these costs, as well as forecasting potential benefits and their magnitude, can be carried out.

In business enterprises, economics is the bottom line. The benefits gained by using or implementing a technology should outweigh the costs. In most cases, only monetary benefits are considered. While still placing emphasis on monetary profit and effectiveness of the new technology, attention is also paid to environmental costs and benefits and become factors in choosing an appropriate technology as well.

Regardless of the scenario for implementation of technology, costs need to be considered. A company considering licensing or purchasing the technology (depending on intellectual property status) would need to carefully consider all of the costs involved in implementing a new technology. Some issues that are relevant to the adoption of a technology include: site preparation, permitting and regulatory cost requirements, equipment, fixed costs, reoccurring costs, startup expenses, labor, supplies, consumables, residuals, and operation and maintenance (O&M) costs.

Market evaluation

The evaluation of market aspects is based on the identification and assessment of a market demand for the technology. An iterative process of defining potential market niches for the technology and the asking of potential buyers or users of products in this niche is carried out to determine if there is a potential demand for this technology. Only broad estimations, if any, of the magnitude of product demand are identified to provide justification for the selection of target markets. In this section of the STEP, an analysis of the growth potential of the technology is identified. One might ask the question: Is this a technology that will be purchased by only a few specialized users, or is the demand likely to exceed niche boundaries?

A market evaluation also consists of a competitive evaluation. In this process, competitors for each potential application are identified and compared with the technology in question in terms of effectiveness, cost, and ease of use or process integration.

Perception evaluation

The way that end-users feel about the technology and its potential to be an attractive product or technique for their utilization is addressed in the STEP methodology as the perception evaluation. This type of evaluation is more helpful when a technology has made it well past the bench and pilot scale to full-scale implementation, so that people may have had a chance to hear about the technology and its potential advantages and disadvantages. However, it may be equally relevant in earlier stages of development for certain technologies (e.g., genetically engineered microorganisms) that have a good or bad connotation.

Regulatory/policy evaluation

All technology industries and markets are not alike, varying through the unique particular characteristics of the technology and the overlay of those characteristics on the physical and cultural aspects of potential geographic locations for the application. For example, climate aspects may limit the efficacy of a technology. Furthermore, not every sector or location will be equally accepting of a technology due to regulatory policies. In these cases, it may be particularly helpful to identify and include experts with knowledge of these specific factors for the evaluation process (Martyniuk 2003; Brown 1997; Jain et al. 2003; Chifoset al. 1997; Weick et al 2003)

5. Methodology

In real world applications, precise data concerning commercial potential factors aren't available or are very hard to be extracted. In addition, decision makers prefer natural language expressions such as "high", "low", "average", etc., rather than numerical values in assessing commercial potential.

Fuzzy logic offers a systematic base in dealing with situations which are ambiguous or not well defined. Indeed, the uncertainty in expressions such as "low commercial potential" or "high commercial potential", which are frequently encountered in the commercial potential literature, is fuzziness. Commercial potential is a multidimensional, but also vague notion, which for reasons of analysis has been broken down by the researchers into several distinct types. Mathematical models have difficulties in dealing with the direct measurement of commercial potential. To accomplish this task it is important to take into account the ideas people have about the quantification of the observable parameters of the notion. Algebraic formulae fail in putting together the various components of commercial potential. On the other hand, by a suitable representation of human expertise concerning the combination of the flexibility parameters, we achieve a knowledge-based measurement which overcomes these problems. The key idea is to model human inference, or equivalently, to imitate the mental procedure through which experts arrive at a value of commercial potential by reasoning from various sources of evidence. These experts could be researchers, technology marketing and commercialization team, potential transferees, and consumers of commercial product of technology or any other qualified individual [Khoshima 2003; Khoshsima 2004).

This method was used by Tesourvelodis and Phillis at 1997 and 1998 for measuring manufacturing flexibility and assessing machine flexibility at 1998, stock evaluation by Dourra and Siy at 2001, measuring manufacturing competence by Azzone and Rangone at 1996, personnel assessment by Capaldo and Zollo at 2001, assessing operational risk of software by Xu et al at 2003, and life cycle assessment by Gonzalez et al at 2002 (Azzone et al. 1996; Capaldo et al. 2001; Dourra et al 2001; Matson et al 1999; Tsourveloudis et al. 1998).

Fuzzy logic has been successfully applied for simplifying of decision making in environments characterized by uncertainty and imprecision. It is based on the idea of building a model capable of simulating the way an expert elucidates. The main breakthrough of fuzzy inference with respect to traditional mathematical models lies in the fact that the relationship between inputs and outputs is not determined by complex equations, but by a set of logical rules, reflecting an expert's knowledge. It simplifies the process of taking decisions by simulating the way of reasoning of a human expert in environments characterized by uncertainty and imprecision. Fuzzy logic is applied in the building of fuzzy systems, which establish the relationship between an input space and an output one [Capaldo et al. 2001; Dourra et al 2001].

The breakthrough regarding traditional mathematical models lies in the fact that the relationship is not determined by complex mathematical equations, but by means of a set of logical rules that reflect the way of reasoning of an expert. These rules consist of an antecedent (in which several input variables are related by means of logical operators) and a consequent (where the same process occurs amongst the output ones) (Gonza´lez et al, 2002).

In this paper, fuzzy systems are designed, in several steps: fuzzification, aggregation of antecedents, inferencing, composition, and defuzzyfication. The core of the fuzzy inference system is based on the set of rules defined to link input and output spaces, in an attempt to simulating the way an expert reasons (Dubois and Prade, 1996). In this case, the antecedents link all the possible combinations of categories in qualitative and quantitative variables by means of the operator AND. The key idea of our model in measurement is the involvement of all distinct types and corresponding operational parameters in the determination of the overall commercial potential. As before is described, this is implemented via multi-antecedent fuzzy If-Then rules, which are conditional statements that relate the observations concerning the allocated types (If-part) to the value of commercial potential (Then-part).

Suppose $i\,A_i$, i = 1, 2…N, is the set of commercial potential components and $i\,LC_i$ the linguistic value of each component; then the expert knowledge general rule is

If A_1 is LC_1 AND……………….AND A_n is LC_n Then $COMP_T$ is LC_T

Where LC_T representing the set of linguistic values for commercial potential $COMP_T$. All linguistic values A_i and $COMP_T$ are fuzzy sets like what is shown in Fig. 3. Commercial potential is a multidimensional, inherently vague notion and an essential requirement in its measurement is the involvement of human perception and beliefs. The process of assigning values using a Likert scale is fuzzy by nature. This process has been depicted in Fig 4. The respondents were asked to answer the questionnaire using a 5-point Likert scale. To design fuzzy system, at the first and second level, we used a 5-point scale of Chen and Hwang. Chen and Hwang turned Likert scale into fuzzy number.

At the third level, a 5-point scale questionnaire is used. Hence the input data of fuzzy system are crisp number and in the process of fuzzy system they will change to fuzzy number and final output of the system is fuzzy number. Then by using defuzzification rules, the final result exchange to crisp number.

In addition, each dimension breaks into some measurable indices. At the first level, one fuzzy system with three inputs (technology area, market area and legal area) and one output (commercial potential) is designed. At the second level two fuzzy systems for technology area and market area with five inputs (technical, process, market, economic and Perception Evaluation) and one output for each of components are designed and then for entering data to fuzzy system data is aggregated.

At the second level, legal area due to its one input (regulatory/ policy evaluation) doesn't need a fuzzy system and hence value of regulatory/ policy evaluation straight forwarded to legal area.

Therefore, we have 125 rules at first level and 25+ 125 rules at second level (Fig 4). After gathering questionnaires the degree of each component is determined as fuzzy triangular numbers and the fuzzy systems designs in MATLAB software.

After entering data to MATLAB, the system runs to measuring commercial potential for a candidate technology in Research Institute of Petroleum Industry (RIPI)[2].

6. Discussion

The described framework has been based upon
(1) the most recent theoretical state-of-the-art literature; and
(2) the empirical cases illustrated in this literature.

An empirical research is necessary to enrich the framework and improve its completeness, clarifying: the factors considered by companies during the valuation process; how the management of different elements that compose the framework, has an effect on the process; and the main issues and the critical problems faced by the appraiser during the whole process.

The Business Development Division has been appointed to manage the economic and industrial exploitation of technology belonging to the RIPI. The case study has been conducted to:

- apply the framework to show the meaning of activities and constraints in a real and specific context;
- enrich and complete the framework; and
- highlight and discuss the problems faced by the appraiser during the whole process.

The use of key technological information has been an effective approach in many research contexts.

Typically, these respondents are researchers in the specific area, experts of technology management, experts of commercialization and technology marketing, traders and consumers of commercial product of technology. The support for their use stems from their perception of commercial potential and different aspects of the technology and its considerations. Therefore, the respondents profile considered ideal for this study.

[2] One Of The Greatest Research Institutes In The Middle East

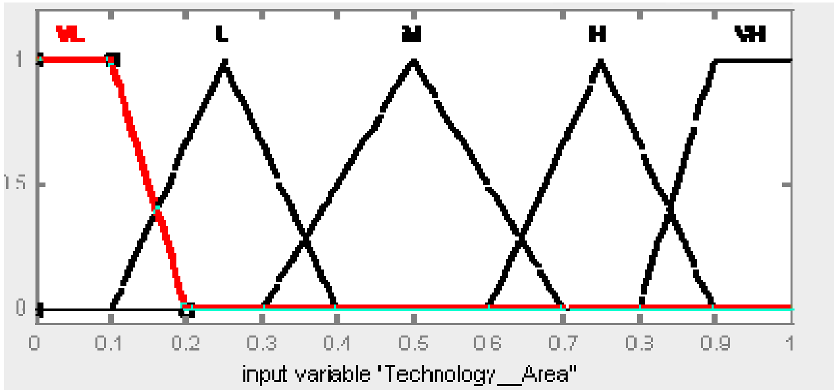

Figure 3: Membership function of 5-point Likert scale based on Chen and Hwang

Questionnaires were distributed in three groups (technology management experts, catalyst experts (researchers) and traders & consumers of catalyst) for determining the degree of component and designing the fuzzy system. Hence, we distributed a questionnaire among technology marketers and commercialization and technology management experts for designing fuzzy systems. Researchers of catalyst area and potential consumers of commercial product of technology and potential transferee of technology were profiled and the instrument was pre-tested among this constituency to ensure that these respondents understood the questions and could provide informed responses. The items were randomly dispersed throughout the questionnaire. In sum, the data collection process yielded assessments of 30 respondents of commercial potential components within their respective area.

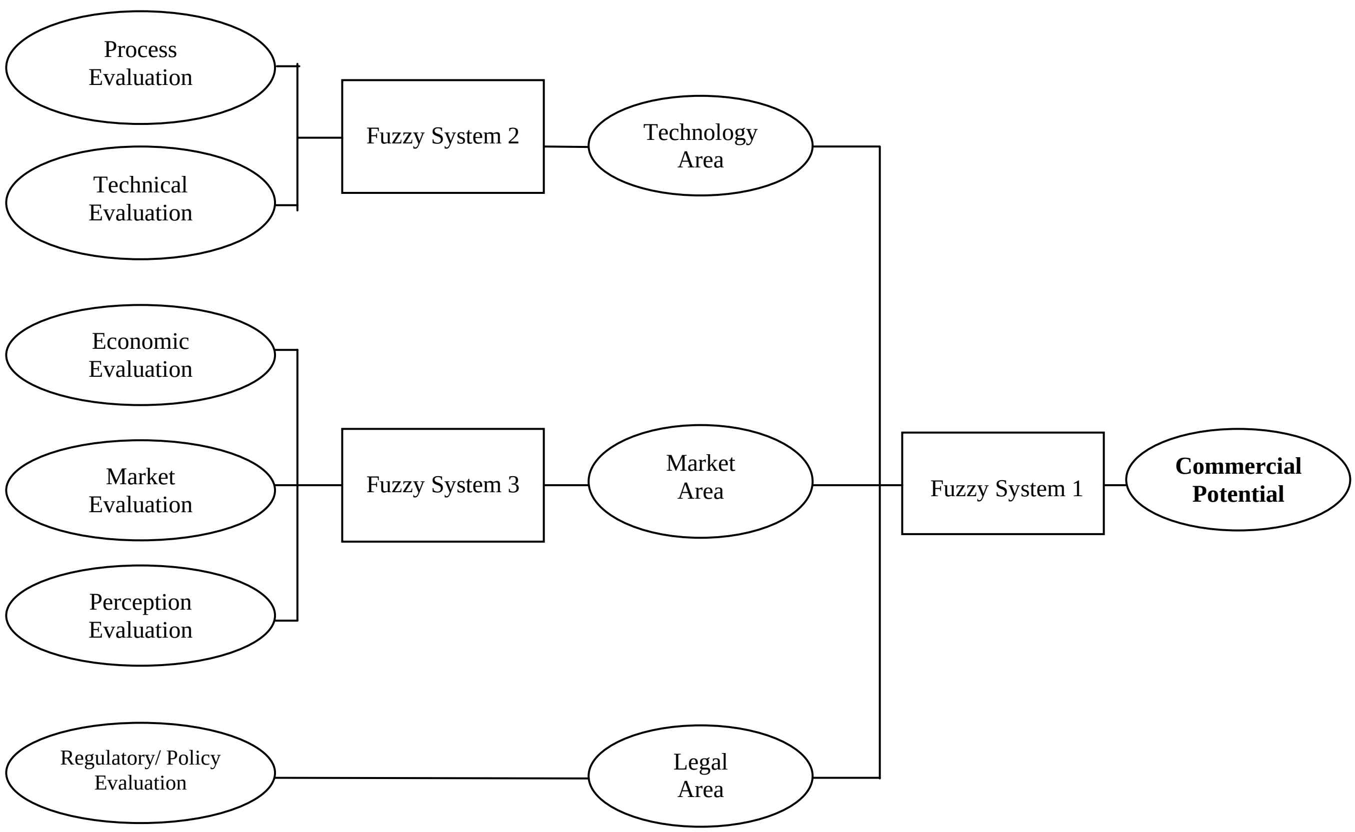

Figure 4: Fuzzy systems and subsystems

7. Data analysis and conclusion of the empirical study

Based on the responses provided by a panel of experts, the technologies were ranked as to likelihood of successful commercialization. Then, the most likely candidate technology was analyzed using six evaluations: the technology evaluation, the process evaluation, the economic evaluation, the market evaluation, the perception evaluation, and the regulatory/policy evaluation.
After gathering questionnaires, following results for the technology evaluation from six dimensions; technical, process, economic, market, perception, and regulatory/policy were acquired. The results are depicted in Table1.

Table1. Results of the technology evaluation from six dimensions

Items	Scores based on 0-1
Process Evaluation	0.25
Technical Evaluation	0.833
Economic Evaluation	0.8
Market Evaluation	0.75
Perception Evaluation	0.708
Regulatory/ Policy Evaluation	0.593

At the next stage these results were entered to fuzzy system. After running fuzzy system, following results were acquired for the Technology Area, Market Area, Legal Area and commercial potential of the technology.

Table2. Fuzzy results of the technology evaluation

Technology Area			Market Area			Legal Area			Commercial Potential		
L	M	U	L	M	U	L	M	U	L	M	U
0.44	0.571	0.7	0.8	0.845	0.89	0.48	0.593	0.7	0.66	0785	0.9

The interpretation of the table is as follows: L state pessimistic, M most possible and U optimistic conditions. For example at technology, L= 0.44 point out to technological ability toward commercialization pessimistically, M= 0.571 point out to technological ability toward commercial potential most possibility, and U= 0.7 point out to technological ability toward commercial potential optimistically.
At the end, commercial potential of the candidate technology for development was calculated and it was located between 0.66 - 0.9 and in the most possibly was 0.785 which shows high potential of technology to successful commercialization.

8. Conclusion

A model for making technology investment decisions
The viability of a technology is not determined by technical considerations alone. Financial, legal, regulatory, market, and numerous other factors come into play role before a research organization can begin developing and commercializing a technology.
To do that a technology investment decision model should be implemented and both technical and non-technical concerns should be considered in the technology development process

The model should not be prescriptive, but should be provocative. This study aim is to highlight the importance of these [non-technical] factors. These should be considered earlier in the technology development process..
Certain criteria must be satisfied before a potential technology should be passed to the next stage of development. Up to gate four [prior to engineering development], technology developers should have lots of R&D discretion. More attention should be paid on science rather than engineering." After gate four, however, technology development costs rise considerably. At that point andeyond, it is imperative that technologies being developed meet the requirements of the users. If not, the technology should be killed.

Even before gate four, however, the model suggests that technology developers begin assessing the potential for commercializing a technology. Commercialization was traditionally considered the last step in the technology development process that came after a demonstration. In reality, we need to prepare earlier in the process."

Thinking a strategy is necessary for handing off a technology from developer to user. This will help bridge what is often called "the valley of death" - the gap that occurs when technology developers stop funding a project before it reaches the stage where technology users are willing to implement it. Private-sector companies are often caught in the middle with a partially developed product they can't sell.

It is suggested that technology developers, users, private-sector companies, stakeholders, regulators, and others be included in the technology development process in a formal evaluation, specifically prior to engineering development. Whether that happens, is up to each of the focus area management teams.

With the early identification and measurement of commercial potential, by given direct access to the right kind of people, a research institute with a new technology would be able to achieve four fundamental objectives:

1. Validate commercialization:

That is, determine if one technology has the overall business potential it will need in order to justify commercialization in the first place or justify the broadening of commercialization.

2. *Realistically assess utility of the technology*:

These people could determine key applications, variations, modifications of the technology, i.e. ideas for using the technology, that would directly address known and specific problems and needs that exist in the markets or in industries in which they have.

By connecting real-world needs with the attributes of a given technology, such ideas offer the potential to create new competitive advantages for customers of products that could result from the application of the technology in question considerable and up-to-the-minute experience.

3. Accurately target commercialization:

These people could help the research organizations to target those specific markets, industries or industrial sectors which could potentially utilize the technology in a cost-effective manner…now! ("now" meaning short- to mid-term) and they could identify the leading companies in the world, who could most benefit from involvement with the technology; as a customer, or co-developer, or licensee or through some other form of partnership or alliance.

4. Initiate commercial actions:

Most of all, access to such people could provide an immediate path to commercialization, since such people are themselves in a position to do something about their own ideas and suggestions. That is, they can begin to take the critical precommercialization steps with the sponsoring company to determine technical and economic feasibility.

In this paper, based on the STEP methodology a fuzzy logic measurement system was designed to quantify the overall likelihood of commercial potential (i.e. successful commercialization) of technology. Then the system was run to measure commercial potential of a specific technology (a kind of catalyst).

Finally it is essential to know that, almost all the Commercialization Assessment Index (CAI) is comprised of several factors, but the technology commercialization process is not merely dependent on the selected forces or factors.

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