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# Design of an Intelligent System for Evaluation of Science Parks

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## KEYWORDS

Science and Technology Parks,
Fuzzy Expert Systems,
Fuzzy Logic,
Evaluation

## ABSTRACT

*The science parks have important role in development of technology and are able to make economic growth of the countries. The purpose of this paper is the presentation of a Fuzzy Expert System (FIS) as Intelligent Systems to evaluate the science and technology parks. One of the problems for evaluating Science and Technology parks is to have the high number of criteria and science parks which AHP method and some other MCDM methods that with them have evaluated parks are not suitable practically. Therefore presenting a system which is able to compare this high number of science parks with many criteria is one of the findings of this paper. At the end, we have described a numerical example. This paper is a useful information resource for managers of Science and Technology parks and interested parties to invest and to recognize the science parks better.*



## 1. Introduction

Science and Technology parks are known as one of the centers for improving and training knowledge and economy. Evaluating the performance of science parks can be a rather complex undertaking and is characterized by approaches that are not unequivocal. This complexity is highlighted by some contributions that have appeared in the literature in recent years[1], whose assumptions have been confirmed by empirical studies carried out on a broad sample of subjects (IASP study). The tools used for this type of evaluation can be very different: in some cases only financial criteria are used (e.g. level and type of investments made, turnover generated by the growth of the services provided by the start-up and the development of companies within the Parks, returns on investments, etc.), in others innovation-related indicators are used (e.g. number of start-ups, number of registered patents, number and type of new products launched by incubated firms, etc.)[2]. Given the increasing number of science parks that are being set out both in highly industrialized as well as emerging countries, the problem of measuring the effectiveness of innovation supporting policies is becoming paramount both in practitioners and academicians agenda[2]. The complexity of measuring Science parks performances has evolved over time as their mission has progressively broadened.

The world's first science park started in the early 1950`s and foreshadowed the community known today as silicon valley. In 1980, the Taiwan government decided to establish its first science park, Hsinchu Science Park. In Hsinchu city, for the purpose of attracting high-tech firms to create industry clusters here. In the past two decades, the development of Hsinchu Science Park was an epitome of development

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of Taiwan's high-tech industries. Currently, there are six high-tech industries developed in the Hsinchu Science Park [3]. The earliest US science parks in the fifties and sixties [4, 5] were made up of physical spaces located within or near university campuses where research and development labs, typically those of multinational firms, were established [6, 7, 8]. A second type of primordial science parks were created to exploit new modes of industry/ university collaboration and could be thought of as an extension of private/ public R&D facilities [2]. Finland, Sweden and Norway are emblematic examples of this further approach to science parks concept [9, 10].

They were soon followed by the establishment of central-southern Europe science parks, which were made up of physical locations (often the original factories that had been abandoned) where, in addition to industrial research labs born out of Industry/university collaboration, there were also the incubators of new firms that established irrespective of any academic linkage. Also, this new form of science parks were including service centers providing firms with such services as marketing advising, logistics outsourcing, funding etc [11, 2]. By the mid-1990s, 310 science parks were developed in 15 countries in the European Union, where 14790 firms were located on parks, employing 236, 285 employees [12, 13].

As many experts cooperated in the assessment of parks, fuzzy group analytical hierarchy process (FGAHP) was used [46]. If the number of alternatives and criteria are large, the AHP and FGAHP method cannot be applied in practice [15]. To improve the ranking, a model to determine the number of pairwise comparisons is significant [47, 48].

Also design of an intelligent system is usefull for evaluation science parks [45]. Since It is possible to evaluate the STPs with many options and criteria, The AHP method and some other MCDM methods that with them has evaluated parks, are not suitable practically [14, 15]. The purpose of this paper is presenting a fuzzy expert system which is able to evaluate the considered STPs with many criteria and the high number of the parks. This paper is organized as follows. Section 2 discusses Literature review & Science and technology parks. Section 3 explains fuzzy expert systems. Section 4 provides a numerical example of the model.

## 2. Literature Review

### A: Science and Technology Parks

Science parks are sources of entrepreneurship, talent and economic competitiveness for our nation and are key elements of the infrastructure supporting the growth of today's global knowledge economy. They enhance the development, transfer and commercialization of technology. As Science Park harness the combined power of education, research and private investment. The result is new jobs, new industries and solutions to age-old problems of mankind. They connect the innovative thinkers of out time and harness the most powerful resource of the 21st century: mind power [3].

The science parks' role is to enable academics at the local university to commercialize their research ideas, and to provide well established businesses and small businesses, who are using and developing sophisticated technologies and prestigious accommodation [13, 12]. The development of Science Park in many countries clearly received its early impetus from the United States' experience [16].

Taiwan was no exception [3]. Science parks were generally established with two primary objectives in mind. The first objective of a science park is to be a seedbed and an enclave for technology, and "to play an incubator role, nurturing the development and growth of new, small, high-tech firms, facilitating the transfer of university know-how to tenant companies, encouraging the development of faculty-based spin-offs and stimulating the development of innovative products and processes". The second objective is to act as a catalyst for regional economic development or revitalization and to promote economic growth [17, 18]. Generally, Science parks have numerous goals, in terms of their impact on the firms and regional economic development. Goals relating to firms include facilitating university and research institute technology transfer, promoting the formation of NTBFs, attracting high-tech firms and fostering strategic alliances/ networks.

Objectives relating to regional impacts include economic development, job creation, and enhancement of the image of the regions [19, 20]. In other words, a science park is a learning site, combining in a pre-established territorial area productive, scientific, technical, educational, and institutional agents, based on the assumption that the co-location of these agents is expected to enhance the technological and innovation capability of the host region [21]. The vocabulary used to describe and analyze science parks–including terms such as research parks, technology parks, innovation centers, and techno poles-often differs from one case to another, suggesting a need to distinguish different types [22, 23, 24, 25, 26, 27, and 28].

However, in its traditional form, it is argued that a science park exhibits the following components [29]: (1) A scientific component with the presence of universities and technology centers and R&D laboratories that have the mandate to produce and diffuse innovation and technology, (2) A productive environment made up of technological and innovating companies able to diffuse knowledge and technologies to other companies in and off the park. (3) A structural component consisting of specialized services offices to support technology transfer [21].

The definition of IASP about Science Park is: A science park is an organization managed by specialized professionals whose main aim is to increase the wealth of its community by promoting the culture of innovation and competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a science park stimulate and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes and provides other value-added services together with high quality space and facilities [30].

The Association of Universities and Research Parks (AURP) states that a research park is a property-based venture which has: (1) Existing or planned land and Buildings designed primarily for private and public research and development facilities, high technology and science based companies and support services, (2) A contractual and/or formal ownership or operational relationship with one or more universities or other institutions of high education and science research, (3) A role in promoting research and development by universities in partnership with industry, assisting in the growth of new ventures and promoting economic growth, and (4) A role in aiding the transfer of technology and business skills between the university and industrial tenants. The park (or incubator) may be a non-profit or for-profit entity, owned wholly or partially by a university or a university related entity [31].

The United Kingdom Science Parks Association (UKSPA) defines a science park as a business support initiative whose main aim is to encourage and support the start-up and incubation of innovative, high-growth, technology-based businesses through the provision of infrastructure and support services, including: (1) Collaborative links with economic development agencies, (2) Formal and operational links with centers of excellence such as universities, higher education institutions and research establishments, and (3) Management support actively engaged in the transfer of technology and business skills to small and medium sized enterprises [13, 31].

Some Researches have been done in Science and Technology parks [2, 3, and 32]. The current literature on science parks sits within two broad areas of study: (a) The ''institutional'' perspective focuses on whether science parks confer competitive advantages to the tenant firms, as well as positive spillover effects to firms located in its vicinity and the regional economy; (b) the economic geography perspective considers a science park and its surrounding region as an entity consisting of specialized firms with an evolving structure of interfere linkages and agglomerative effects [17].

There has been a great deal of analysis of the science parks located in Europe and especially in the UK. Reference [33, 13] shows the first challenge on the success of the UK science parks in the light of the UKSPA definition [13, 33]. Reference [34] shows the survey on in-science parks and out-science parks firms in the UK. They surveyed firms in 35 science parks. Thus, they argue, the role of the science parks in UK may be proved critical for the survival of small high-tech firms .

Another paper surveys the Surrey Research Park and examines the links between the local university and the firms located on the research park [35]. Another one surveyed the firms located on the Western Australian Technology Park in order to defend his argument about the non-linear model of innovation [36]. Reference [37] evaluated the performance of the Hsinchu Science Park (HSP) in Taiwan and argue that the HSP has become the first hi-tech industry development model in Taiwan .Year 2006,A paper was presented with the title of "evaluation of functionality of Science and Technology Parks" which was purposed to present theory-grounded methodological framework to science parks performance measurement and some practical suggestions useful for the design and the implementation of a Science Park's (SPs) performance evaluation [2].

In another paper in year 2002, it covers the Role of STPs in development of the less developed countries and examines the science parks in a peripheral European country, Greece [13]. The findings indicate that the picture of the three science parks of Greece is not the same in terms of the links between university and industry. Informal links have been developed between the firms and the local university, however, only the firms located at one Science Park have developed formal links, while the formal links of the companies of the other two parks are at the infant level at this time. Synergies between the on-park companies are limited only in commercial transactions and social interactions.

The research type synergies are completely absent in all three parks. Generally, it shows there is no relation between industry and university. Year 2004, another paper applied the Analytic Hierarchy Process (AHP) method to evaluate the 6 high-tech industries for the introduction and development in the new science based industrial park Hsinchu in Taiwan [32]. The effort resulted in seven evaluation criteria with one, the ''market potential'' having the highest weight, followed by ''technology level'' and ''government policy''.

Year 2006, another paper applied Data Envelopment Analysis (DEA), a multiple inputs–multiple outputs evaluation Method and Malmquist indices, to analyze the comparative performances of the six high-tech industries currently developed at Taiwan's Hsinchu Science Park [3]. In year 2004, another paper studied the Growth of Korean Daeduk Science Park and Economic Development in 30 years [3]. Another article (2006) which is about Emergence and Growth of

Mjärdevi Science Park in Linköping, Sweden, traces the historical events related to the creation of Mjärdevi Science Park that have influenced its technological and industrial development [21].
Next article (2009) is about proposing an improved grey model using a technique that combines residual modification with Markov chain model, applied as a case study to annual output of Taiwan Hcinchu Industries science park, could clearly improve forecast accuracy of original Grey forecast model .There are some researches Being done on Expert system and Fuzzy logic also .There is an article which focusing on the rating, ranking and valuing of firms with using of Fuzzy logic and expert systems in order to provide a score for the firm(s) under consideration, representing the firm value-creating power and The fuzzy expert system introduced is capable of dealing with both quantitative and qualitative variables and integrates financial, managerial and strategic variables [38].

**B. Fuzzy Expert System**

The world of information is surrounded by uncertainty and imprecision. The human reasoning process can handle inexact, uncertain, and vague concepts in an appropriate manner. Usually, the human thinking, reasoning, and perception process cannot be expressed precisely. These types of experiences can rarely be expressed or measured using statistical or probability theory. Fuzzy logic provides a framework to model uncertainty, the human way of thinking, reasoning, and the perception process. Fuzzy systems were first introduced by Zadeh (1965). Reference [39] shows that in 1973, Professor Lotfi Zadeh proposed the concept of linguistic or “fuzzy” variables. Think of them as linguistic objects or words, rather than numbers. The sensor input is a noun, e.g. “temperature”, “displacement”, “velocity”, “flow”, “pressure”, etc. Since error is just the difference, it can be thought of the same way. The fuzzy variables themselves are adjectives that modify the vary-able (e.g. “large positive” error, “small positive” error, “zero” error, “small negative” error, and “large negative” error). As a minimum, one could simply have “positive”, “zero”, and “negative” variables for each of the parameters. Additional ranges such as “very large” and “very small” could also be added to extend the responsiveness to exceptional or very nonlinear conditions, but aren’t necessary in a basic system [39].
A fuzzy expert system is simply an expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data [40]. The rules in a fuzzy expert system are usually of a form similar to the following:
If A is low and B is high then X = medium, where "A" and "B" are input variables, X is an output variable.
Here low, high, and medium are fuzzy sets defined on A, B, and X respectively. The antecedent (the rule’s premise) describes to what degree the rule applies, while the rule’s consequent assigns a membership function to each of one or more output variables. In what follows, the two most popular fuzzy inference systems are introduced that have been widely deployed in various applications. The differences between these two fuzzy inference systems lie in the consequents of their fuzzy rules, and thus their aggregation and defuzzification procedures differ accordingly.

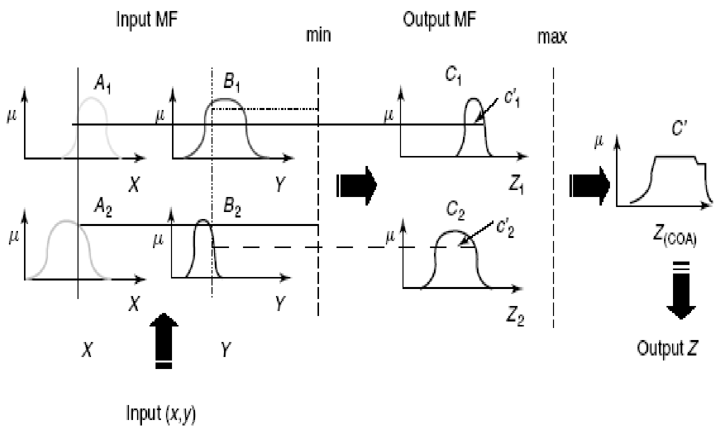



**Fig. 1. Mamdani Fuzzy inference system using min and max for T-norm and T-conorm operators.**

According to Mamdani, fuzzy inference system –see Figure 1– the rule antecedents and consequents are defined by fuzzy sets and have the following structure [41]:

*If x is A1 and y is B1 then z1 = C’1* (1)

There are several defuzzification techniques. The most widely used defuzzification technique uses the centroid of area method as follows:

*Centroid of area ZCOA = _Z µA(z) z dz _Z µA(z) dz* (2)

Where µA(z) is the aggregated output MF.

A paper proposed an inference scheme in which the conclusion of a fuzzy rule is constituted by a weighted linear combination of the crisp inputs rather than a fuzzy set [42]. A basic Takagi–Sugeno fuzzy inference system is illustrated in Figure 2 and the rule has the following Structure:

*If x is A1 and y is B1, then z1 = p1x + q1y + r1* (3)

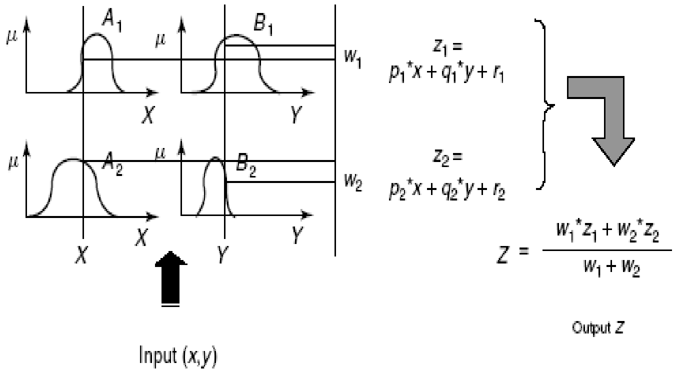



**Fig. 2. Takagi-sugeno fuzzy inference system using a min or product as T-norm operator.**

Where $p_1$, $q_1$, and $r_1$ are linear parameters. TSK Takagi–Sugeno Kang fuzzy controller usually needs a smaller number of rules, because their output is already a linear function of the inputs rather than a constant fuzzy set.

Fuzzy expert system modeling can be pursued using the following steps:

**1.** Select relevant input and output variables. Determine the number of linguistic terms associated with each input/output variable. Also, choose the appropriate family of membership functions, fuzzy operators, reasoning mechanism, and so on.

**2.** Choose a specific type of fuzzy inference system (for example, Mamdani, Takagi–Sugeno etc.). In most cases, the inference of the fuzzy rules is carried out using the 'min' and 'max' operators for fuzzy intersection and union.

**3.** Design a collection of fuzzy if-then rules (knowledge base). To formulate the initial rule base, the input space is divided into multidimensional partitions and then actions are assigned to each of the partitions.

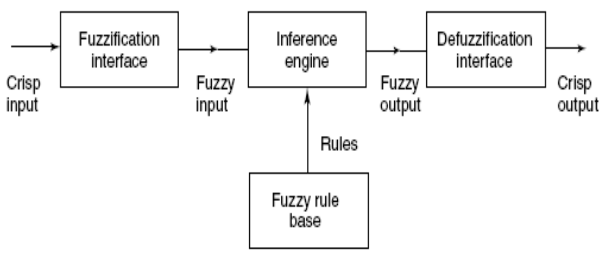



**Fig. 3. Basic architecture of a fuzzy expert system**

Evolutionary search of fuzzy rules can be carried out using three approaches. In the first method (Michigan approach), the fuzzy knowledge base is adapted as a result of antagonistic roles of competition and cooperation of fuzzy rules. The second method (Pittsburgh approach), evolves a population of knowledge bases rather than individual fuzzy rules. Reproduction operators serve to provide a new combination of rules and new rules. The third method (iterative rule learning approach), is very much similar to the first method with each chromosome representing a single rule, but contrary to the Michigan approach, only the best individual is considered to form part of the solution, discarding the remaining chromosomes of the population. The evolutionary learning process builds up the complete rule base through an iterative learning process [43], [44].

## 3. Research Methodology

The major steps followed in the practical study of this research, have been implemented in numerical examples. In this regard, for designing Fuzzy Expert System, the following steps have been done: Step 1: Selecting the Input and output variables with the use of previous studies. Besides, meaningful linguistic states along with appropriate fuzzy sets for each variable should be selected. Step 2: Determining the membership functions for the variables. Step 3: Specifying rules to make clear the relations between Inputs and outputs. Step 4: Developing the Fuzzy Expert System via FIS Tool in MATLAB Software. Step 5: Evaluation Science Parks based on the designed system. In next section, the results of each step have been presented elaborately.

## 4. Results and Discussion

In this section, we are going to illustrate the proposed fuzzy expert system in prioritizing four STPs, STP1-STP2-STP3-STP4 with nine criteria. This criterion are Maturity of the Business, Technological capabilities, Size, Stakeholder's Interests, Managerial capabilities, Professionals qualities, DINGM, Constraints and Venture Capital [17] (see Table1 for notation).

**Tab.1. Description the Parameter**

| No | Parameter's Name | Description |
|---|---|---|
| 1 | Maturity of the Business | the state, fact, or period of being mature a business |
| 2 | Technological capabilities (R&D capabilities) | the development and strengthening of capabilities in R&D and the creation of competitive advantages in specific technology sectors |
| 3 | Size | size of the science and technology park |
| 4 | Stakeholder's Interests | different types of the stakeholder's Interests |
| 5 | Managerial capabilities | different types of the managerial capabilities |
| 6 | Professionals qualities | types of the professionals qualities |
| 7 | DINGM | The Degree of Integration with National or Global Markets |
| 8 | Constraints | a limitation or restriction in the overcrowding, small size of firms, urgent need to move into innovation |
| 9 | Venture Capital | Venture capitalists provide funds and assist in the formation of new high technology business |

The hierarchy of the model is shown in Figure 4.

The followings are the verbal vocabularies for each criterion. To make the system, we have used from the Fuzzy Fis into MATLAB software. The useful commands of MATLAB software which the designed Fuzzy Expert System is working with that, has been presented in Appendix1.

It is mentionable that the maturity of business depends on life cycle of STPs and can be divided into (low, medium, high) according to preparation or planning stage, implementation or operation stage, evaluation stage from the life cycle of park.

The Technological capability or R&D capability ranges from pure science and basic research (involving fundamentally similar techniques and results, but different motivations) to applied research (involving research oriented to more practical, product-related considerations), to exploratory development, (involving prototyping) and to advanced development (involving manufacturing considerations) [17]. It can be divided into the following sections: (Pure science, Basic research, applied research, exploratory development, advanced development).

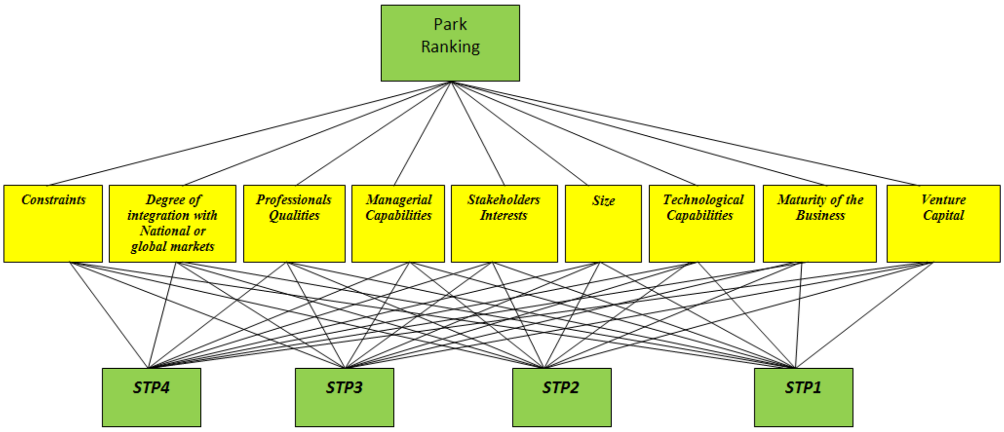



**Fig. 4. The Analytic Hierarchy model of four STPs with nine criteria**

The linguistic variables for criteria and their corresponded membership functions are Figures 5-14 as follows:

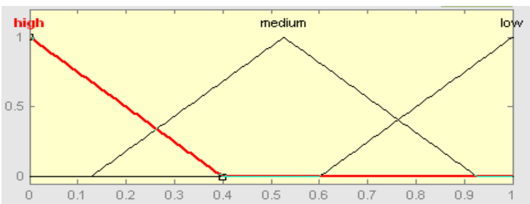



**Fig. 5. Constraints membership function**

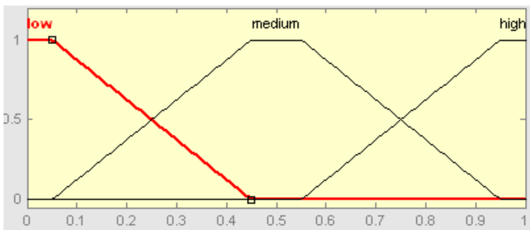



**Fig. 6. DINGM membership function**

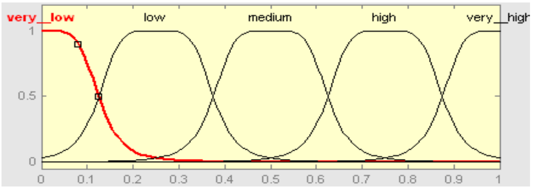



**Fig. 7. Managerial Capabilities membership Function**

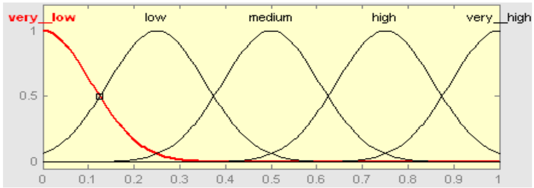



**Fig. 8. Professionals Qualities membership Function**

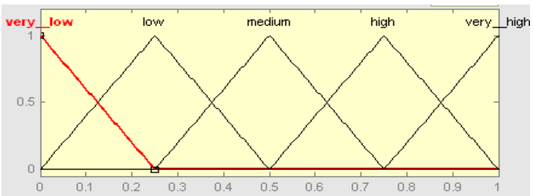



**Fig. 9. Stakeholder's Interests membership Function**

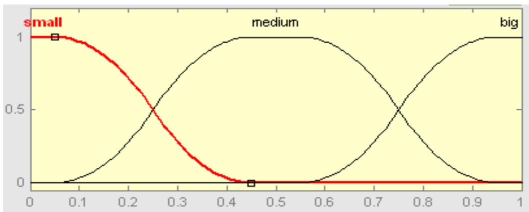



**Fig. 10. Size membership function**

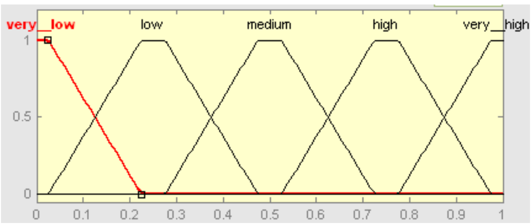



**Fig. 11. Technological capabilities membership Function**

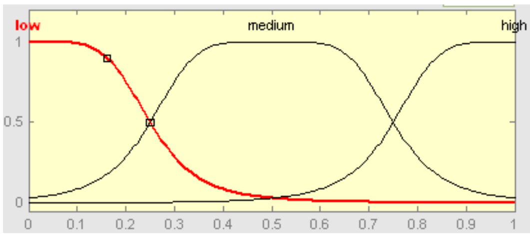



**Fig. 12. Maturity of the Business membership function**

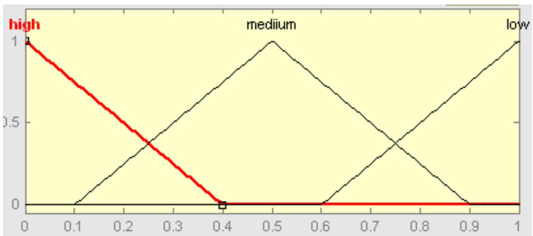



**Fig. 13. Venture Capital membership function**

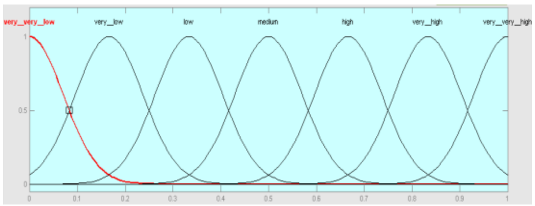


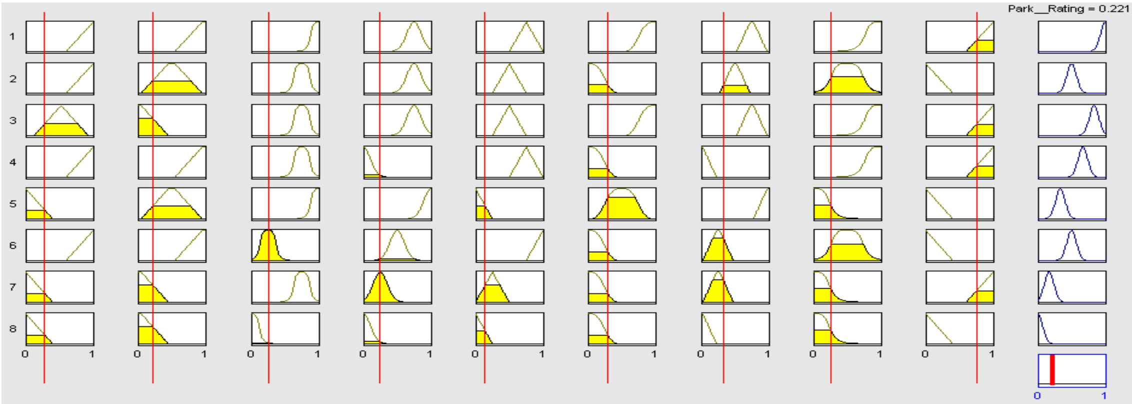
**Fig. 14. Park rating membership function**

According to Expert's opinions and presented Membership functions for every Output and Input variables, Table2 includes the rules of Fuzzy Expert System. It is mentionable that the entire input criterion has been related with AND function.

**Tab. 2.The rules of fuzzy expert system**

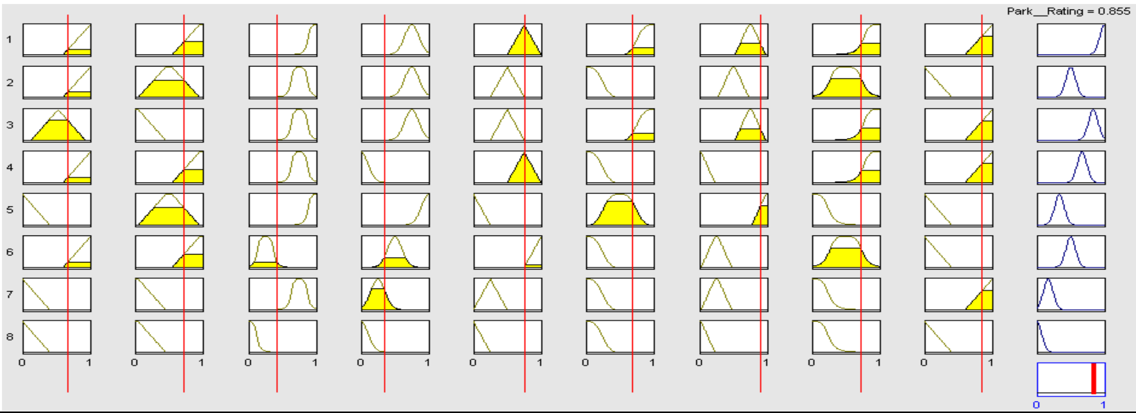
| Maturity of the Business | Technological capabilities | Size | Stakeholder's Interests | Managerial Capabilities | Professionals Qualities | DINGM | Constraints | Venture Capital | Ranking Park |
|---|---|---|---|---|---|---|---|---|---|
| High | High | big | high | Very high | High | high | low | low | Too high |
| Medium | Medium | small | medium | high | High | medium | low | high | medium |
| High | High | big | high | medium | High | low | medium | low | Very high |
| High | Very low | small | high | Very low | Very low | high | low | low | high |
| Low | Very high | medium | Very low | Very high | Very high | medium | high | high | Low |
| Medium | Low | small | Very high | low | Medium | high | low | high | Medium |
| Low | Low | small | low | high | Low | low | high | low | Very low |
| Low | Very low | small | Very low | Very low | Very low | low | high | high | Too low |

After presenting the Rules and designing the considered Expert system, we have evaluated the options by Experts opinions, which the followings are the results for that. By the studies being done, the following output results according to the Figures 15, 16, 17 and 18, In addition to the user interfaces, by the system have been allocated to the Parks.



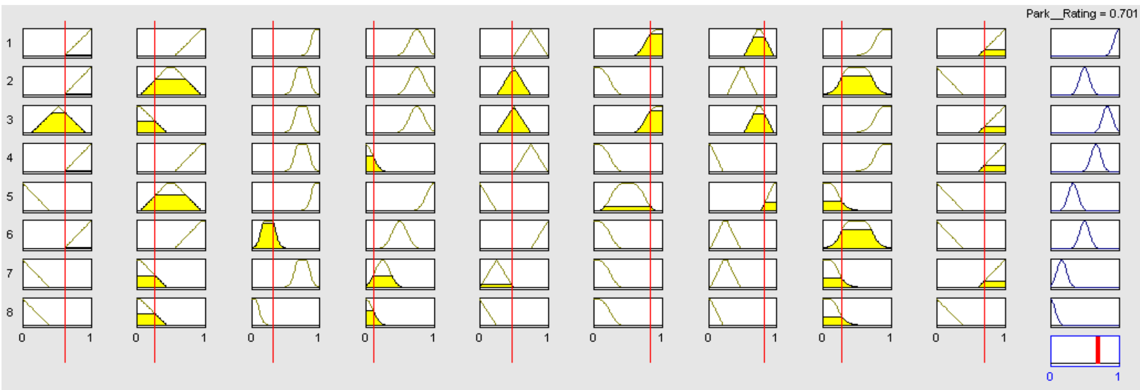

| Constraint | DINGM | Managerial Capabilities | Professional quality | Stakeholder's Interests | Size | Technological capabilities | Maturity of the Business | Venture Capital | Park rating for STP1 |
|---|---|---|---|---|---|---|---|---|---|
| 0.283 | 0.22 | 0.25 | 0.17 | 0.1 | 0.3 | 0.39 | 0.18 | 0.753 | 0.221 |

**Fig. 15. The Output Results in addition to User interfaces: The rule viewer for STP1**



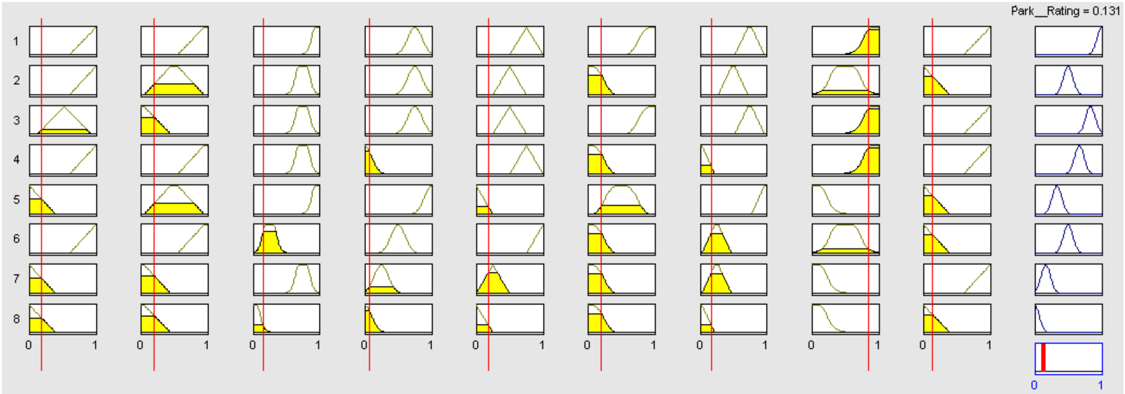

| Constraint | DINGM | Managerial Capabilities | Professional quality | Stakeholder's Interests | Size | Technological capabilities | Maturity of the Business | Venture Capital | Park rating for STP1 |
|---|---|---|---|---|---|---|---|---|---|
| 0.720 | 0.76 | 0.30 | 0.2 | 0.7 | 0.6 | 0.81 | 0.59 | 0.71 | 0.855 |

**Fig. 16. The Output Results in addition to User interfaces: The rule viewer for STP2**




| Constraint | DINGM | Managerial Capabilities | Professional quality | Stakeholder's Interests | Size | Technological capabilities | Maturity of the Business | Venture Capital | Park rating for STP1 |
|---|---|---|---|---|---|---|---|---|---|
| 0.625 | 0.273 | 0.284 | 0.148 | 0.473 | 0.833 | 0.833 | 0.287 | 0.70 | 0.701 |

**Fig. 17. The Output Results in addition to User interfaces: The rule viewer for STP3**




| Constraint | DINGM | Managerial Capabilities | Professional quality | Stakeholder's Interests | Size | Technological capabilities | Maturity of the Business | Venture Capital | Park rating for STP1 |
|---|---|---|---|---|---|---|---|---|---|
| 0.191 | 0.207 | 0.210 | 0.11 | 0.185 | 0.207 | 0.270 | 0.847 | 0.14 | 0.131 |

**Fig. 18. The Output Results in addition to User interfaces: The rule viewer for STP4**

Finally, The review of the outputs of the four parks: STP1, STP2, STP3, STP4, in order as 0.221, 0.855, 0.701, and 0.131, gives us the result that the STP2 Park has the maximum Point and the first priority and the STP4 has the minimum point and the fourth priority. Also, the result of difference between the outputs is the level of difference between the ranks for each of the Science and Technology parks.

## 5. Conclusion

In this paper, we have presented a Fuzzy Expert System to evaluate the Science and Technology parks. One of the problems in evaluating such parks is the high number of them and the criteria. For this purpose, the targets and the goals for designing the Fuzzy Expert System and the method of their functionality and the previous used techniques in the assessment of STPs have been studied and finally with a numerical example, the method of evaluation the STPs according to Fuzzy Expert System has been described. One of the advantages for this method is providing the evaluation of high number of alternatives with the high number of criteria.

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