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The Influence of Research and Development Activities and NanoFab Centers on Product Development in Nanotechnology: Focusing on Solar Thermal Energy and Photovoltaic Technology

Amrollah Dehghani Sanij [a], Taghi Torabi [b*], Abbas Khamseh [c], Alireza Boshehri [d]

[a] *Department of Technology Management, Sciences and Research Branch, Islamic Azad University, Tehran, Tehran, Iran.*
[b] *Department of Economics, Sciences and Research Branch, Islamic Azad University, Tehran, Tehran, Iran.*
[c] *Department of Industrial Management, Karaj Branch, Islamic Azad University, Karaj, Alborz, Iran.*
[d] *School of Management and Soft Technologies, Malek Ashtar University of Technology, Tehran, Tehran, Iran.*

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ABSTRACT

This research aims to determine the influence of fundamental, applied, developmental research and Nanofabrication (NanoFab) centers on the final outcomes achieved by research and development activities, implying product development and value creation in nanotechnology. Data were collected through library studies and field studies in this study and research factors were also identified. To confirm the collected factors, structural equation technique and Smart PLS software were used and after confirming the research factors, the collected data were analyzed using fuzzy inference method and MATLAB software. The achieved results indicated that this field had the most performance despite the minimal influence of fundamental research on the final results of research and development activities and developmental research, while NanoFabs had the poorest performance with the highest influence on the final results of research activities. It is possible to conclude according to the research results that research and development activities at the fundamental and applied levels cannot easily be connected to the end ring, i.e., industry without NanoFab centers, and provide the final product and create value. Furthermore, providing NanoFab or NanoFabs with emphasis on the development of nanomaterial can significantly affect the development of renewable energies.

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1. INTRODUCTION

Fossil fuel-based energy sources such as gas, coal, and diesel are the main energy resources of traditional generators in the power system and, fossil fuel energy production leads to air pollution by increasing the load demands. Thus, development of a Renewable Energy Sources (RES) based system is essential to ensure a reliable, low-pollution and inexpensive energy production [1]. Of course, the high penetration of Renewable Energy Resources (RERs) increases the fault current level of Direct Current (DC) microgrids, and it may cause miscoordination between protection devices [2]. In this regard, nanotechnology as a new wave of technology has a high capacity to transform industries. Many experts call nanotechnology the next industrial revolution that will influence all sciences [3]. Developing and applying nanotechnology is a comparatively new but quickly growing development in the field of renewable energy Achieved advancements indicate that nanotechnology plays a significant role in all fields of renewable energy. In fact, it is possible to state that nanotechnology can play a crucial role in achieving higher and more efficient energy storage and supply [4].

A special headquarter to develop nanotechnology was established in 2003 in Iran because of the significance and application of this technology and the necessity to help develop it. According to the strategic document on nanotechnology development, Iran should have ranked 15th in the three indices of science, technology, and market production during a period of ten years and by the end of 2013. Realizing the fourth rank in science production in 2013 indicates that this plan had been considered highly successful in the science index; however, the other two indices, despite all efforts, had no good global ranking. Iran has 44th rank in the Technology Development Index in the same year with a share of 0.03 % of the global market share. Failing to achieve the objectives determined in technology and market indices as well as the slow speed of innovation in this field, despite the high rate of scientific production, represent a complex issue that required greater investigation [5]. In fact, the companies active in the field of nanotechnology and their market share have not grown in accordance with the growth of fundamental research in this field. It is possible to conclude that the

*Corresponding Author's Email: ttttorabi@gmail.com (T. Torabi)
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improvements made in fundamental research that have taken place frequently at universities have failed to facilitate development of the technology, to present a product and create wealth, and to ensure effective coherence and relationship among fundamental, applied, and developmental researches. Accordingly, this research aims to investigate the strengths and weaknesses of fundamental, applied, and developmental researches in the field of nanotechnology in Iran and to calculate the influence rate of each factor on the final results of research and development activities. Also, this research aims to examine the type of the requirements to create a connection among fundamental, applied, and developmental researches in the field of nanotechnology so that fundamental research conducted at universities yield developmental research in the industrial sector.

Accordingly, Therefore, two questions can be asked for this research:

1 -Why do the industrial sector fail to apply the results of academic research to develop products and create value in the field of nanotechnology?
2- What are the strengths and weaknesses of research and development activities in nanotechnology?

2. LITERATURE REVIEW

Global experience confirms that the countries that have dedicated the greatest costs to conduct different kinds of research are those that enjoy advanced technology and industry [6]. Table 1 shows the top 15 countries in terms of research and development expenditure in 2019. In this table, the United States, China, and Japan are ranked first to third. Another important indicator of R&D is the percentage of R&D expenditures of the Gross Domestic Product (GDP). As shown in this table, South Korea ranks 5th in terms of R&D after Germany. 4.6 % of its GDP is dedicated to research and development, which is the highest value among the 15 countries evaluated [7].

Table 1. Top 15 countries in terms of research and development expenditures

Rank	Country	Expenditures on R&D (billions of US$, PPP)	% of GDP PPP
1	United States	612.714	3.1
2	China	514.798	2.2
3	Japan	172.614	3.2
4	Germany	131.932	3.2
5	South Korea	100.055	4.6
6	France	63.658	2.2
7	United Kingdom	51.702	1.8
8	Taiwan	42.945	3.5
9	Russia	38.549	1.0
10	Italy	33.840	1.4
11	Canada	26.636	1.5
12	Turkey	24.827	1.1
13	Spain	22.468	1.3
14	Netherlands	20.167	2.2
15	Sweden	17.722	3.4

The remarkable thing about emerging technologies, such as nanotechnology, is that these technologies have often been initially developed out of intense research by government research institutes and have gradually encouraged commercial companies to conduct applied and developmental research. In this respect, it is possible to distinguish between the roles of universities, government research institutes, and private companies in the field of developing these technologies [8], but the essential point is that research and development is a dynamic and continuous process of fundamental, applied, and developmental researches. Therefore, it is required that the scientific results related to each stage be used as valuable reserves as input to the next stage [9]. Accordingly, Research & Technology Organizations (RTOs) are the links between scientific research findings on the one hand and technical application on the other, and they are the link that connects universities to industry [10]. NanoFabs centers are the link between academic and industrial researches in nanotechnology and play the role of research and technology organizations in this field. NanoFabs are national, educational, and service centers with free access that have centered on academic and industrial applications to produce nanotechnology products [11].

2.1. Types of research and development activities

It is possible to classify the research and development activities into three main classes: fundamental research, applied research, and development. Therefore, it is required that nearly every activity be performed in particular environments and centers. Also, one should expect specific outputs from each of these centers. In fact, the direct path of research results in universities to end-users has not been defined [12]. Burns & Rajcan [13] stated the most outstanding output of the university in published articles. Ivanˇcevi´c & Lukovi´c [14] introduced factors including the number of articles, number of references, professors, and graduates as the main criteria to evaluate at the academic centers. Also, Zarei et al. [15] stated that universities, research institutes, and the industrial sector were responsible for conducting research and development activities. This study stated the results of research and development activities in universities as the number of articles as well as the indices of research organizations as the costs spent on conducting the research and development, product development, and process or technology development. Furthermore, the output of research and development in the industry has been considered to be patent registration and market development. Maghferati et al. [16] considered the evaluation indices of the research and development department of industrial units as product development, new process and technology, reduction of the production costs, patenting and optimization of the current products, and market development.

Unfortunately, the government has not been significantly successful in promoting commercialization activities in universities after spending large amounts in Malaysia. The Ministry of Higher Education reported in 2008 that only 58 products were successfully commercialized (i.e., 18 %) among 313 projects recognized with commercial potential. This amount was decreased to 6 % in the report published in 2010 [17]. Ali & Sinha [18] expressed the improvement of performance, reduced production costs of commercialized products, and also explained that by presenting new products as an achievement of nanotechnology, the gap between fundamental research and applying the nanotechnology in the industry is one of the current difficulties. Shamsi and Noor Mohammadi [19] considered factors such as the number of patents and the costs spent on conducting the research and development among the evaluation indices of the industrial sector. Chen et al. [20] also mentioned the number of articles and patents as the output of these activities at the national level. Shapira et al. [21] conducted a study on research and development activities in various countries from the stages of exploration to commercialization and considered the articles and patents as research and development indices in universities and industrial centers, respectively, and also considered the number of nanotechnology companies as an index to develop the nanotechnology. Wang & Guan [22] introduced patents as output indices of universities, research institutes, and industry in nanotechnology and concluded that the share of industry in patients was higher than the other two sectors in industrialized countries. Iran Nanotechnology Innovation Council (INIC) [23] has presented indices such as the number of articles, related references, the number of companies, and nanotechnology products separately in various industrial fields. Additionally, Stat Nano [24] statistics and information database produced indices such as the amount of investment, the number of companies, and Nano products in different countries in order to evaluate the final output of research and development activities.

2.2. The role of research and technology organizations in research and development

Research and technology organizations have an intermediary role between industry and university, particularly in developing countries. These organizations form a significant part of the infrastructure to develop science, technology, and innovation and play an intermediary role between research and production sections [25]. In general, research and development organizations are the ones that provide research and development, technology, and innovation services to the government, industry, markets, and other customers. These organizations are mission-oriented which make it possible to increase economic competitiveness and support innovation and small- and large-sized companies in all fields of the economy in order to assist the government [26].

Aleman et al [27] believed that research and technology organizations had a significant intermediate role in innovation systems and concentrated on applied research. Furthermore, the Research Center of the Islamic Consultative Assembly [28] introduced these organizations as mission-oriented groups that try to solve real-world problems and despite the diversity of their activities, emphasize particularly applied research. Figure 1 shows the functions of research and technology organizations in developing and developed countries.

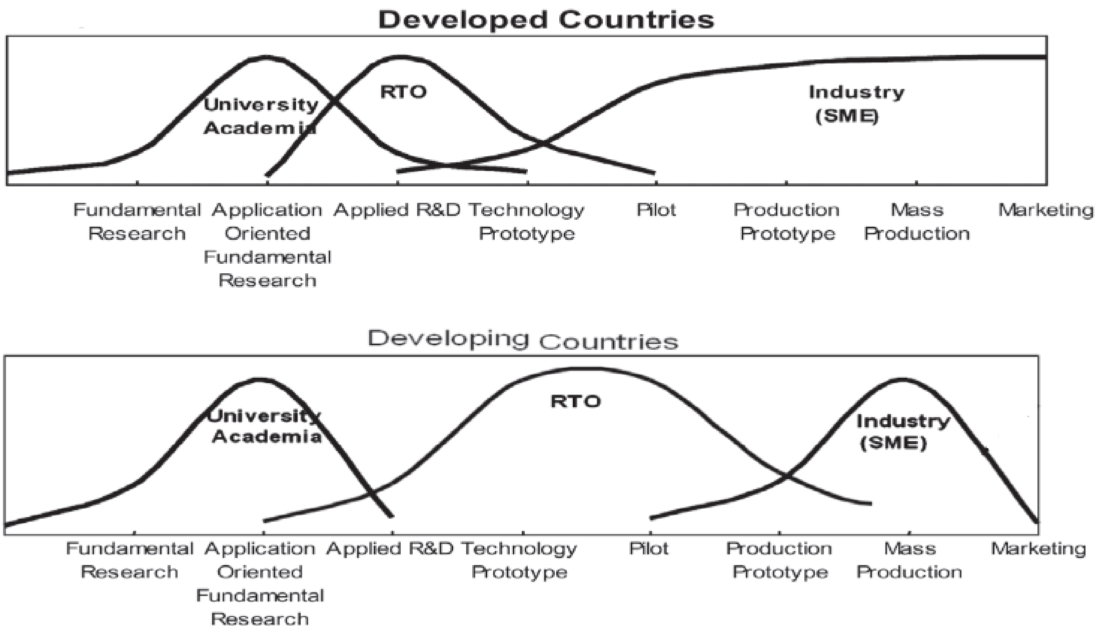


Figure 1. Function of research and technology organizations in developing and developed countries [22]

2.3. NanoFabs or research and technology organizations in the field of nanotechnology

NanoFabs play the role of research and technology organizations in nanotechnology, and various countries have created research and development centers in the field of nanotechnology in order to develop nanotechnology. Nanotechnology can create significant outcomes for industry and economics, but it still is an emerging technology at the university level [29]. NanoFabs are required to transfer technical knowledge and industrial research results to companies that are able to use nanotechnology. NanoFabs cooperated with the universities and the private sector to perform the research activities in nanotechnology and present a diverse range of high-tech services to satisfy the requirements of companies [30]. Chung et al. [31] established one of the strategies for developing nanotechnology in South Korea and there were also two NanoFab centers called the National NanoFab Center (NNFC) and the Korea Advanced NanoFab Center. The National Research Council (NRC) [32] has evaluated the Center for Nano Science and Nanotechnology (CNSNT) in a report as one of the main NanoFabs in the United States. This evaluation introduces this NanoFab as unique organization to provide services to users in all industrial, academic, and government sections and recommends: it is required to increase its focus on the industry as its main customer. The Center for Nano science and Nanotechnology [33] in the United States also declares that this NanoFab is responsible for supporting companies active in nanotechnology in different stages of research and development to manufacturing the product.

2.4. Application of nanotechnology in renewable energies

The materials with nanostructure provide potential advantages for a wide range of renewable energy applications that rely principally on connecters to separate the loads such as photovoltaic, thermoelectric, and electrochemical energy storage. Applying nanostructures enables scientists and engineers to increase the chemical active level for any determined volume in electrochemical systems and increases energy and power density [34]. Also, nanomaterial includes a wide range of materials including Nano crystals, Nano composites, carbon nanotube (CNT), and metal-based nanomaterial that are possible for use to improve renewable energy sources; for example, it is possible that wind energy efficiency be improved using lighter nanomaterial with greater resistance in the rotor blades. Nano-coatings can be used to prevent corrosion in tidal energy equipment, and it is possible to use Nano composites in order to provide higher resistance to drilling machine wear in geothermal energy. Nano crystals have a significant role in increasing the efficiency of solar cells [35]. It appears in this field that nanotechnology is mostly applied in the field of efficient use of solar energy applying photovoltaic (PV) cells. The PV system has a high potential to win energy supply challenges in developing countries. Also, batteries and capacitors are the most significant energy storage systems in energy storage. Carbon nanotube (CNT) is presently applied to replace regular batteries with graphite electrodes [36]. The National Nanotechnology Initiative (NNI) was established in 2001 in the United States to coordinate research and development activities at three levels: science, technology, and nanotechnology. NNI has created national infrastructure using advanced equipment that is required to conduct research, but all groups or institutions cannot afford its cost to purchase it. NNI has also produced NanoFabs in which each one has special features and expertise that can be used to solve complex problems if required [37]. NNI defined the Solar Nanotechnology Project in 2010 in order to understand the phenomena of energy conversion and storage on the Nano scale and improve the properties and features of nanomaterial for solar technology. The following three axes were identified to concentrate on research and development in this project:

1. Improving the production of photovoltaic solar power with nanotechnology;

2. Improving the production of solar thermal energy and its conversion with nanotechnology; and

3. Improving the conversion of solar energy into fuel with nanotechnology [38].

Table 2 presents the summary of factors and indices identified in Section 2.

Table 2. Indices that define the research factors

Factor(variable)	Index
Basic research	Number of articles published in international journals
	H-index of published articles
	Number of professors in the field of nanotechnology
	Number of nanotechnology majors in universities
	Number of nanotechnology graduates
	Laboratories and university equipment
Applied research	Defining the academic theses based on industry requirements
	Producing Prototype
	Number of patents by research centers
	Simulation of a system, product, or process
Developmentl research	Presence of R&D unit in the industry sector
	R&D costs in the industrial sector
	Number of patents by industrial centers
	Reducing the costs for production
	Pilot production (industrial product sample)
NanoFab	Producing the prototypes for a new product according to the requirements related to the industry
	Establishing the specialized laboratories for the final product
	Providing standards and achieving domestic and international approvals
	Granting R&D facilities for startups and knowledge-based companies
	Access to measuring equipment
	Production equipment and methods for production
	Number of researchers
Developing the product and creating value	Increasing the market share
	Number of commercialized products
	Producing nanomaterial
	Producing intermediate nanomaterial
	Number of companies active in producing the nano products
	Longer life of products
	Improving the performance of available products

3. METHODOLOGY

First of all, this study emphasizes the main factors affecting the value creation from research and development activities in the nanotechnology field and also, extracts the characteristics of these factors by the study of research literature, theoretical basis, and exploratory interviews and the related indices have been confirmed from the viewpoint of experts. Thereafter, on the basis of the confirmed factors and indices, the questionnaire of the inquiry was compiled and the validity and stability of it were tested using the Confirmatory Factorial Analysis method and the employment of the Smart PLS3 software. Afterwards, the conceptual method of the research was prepared on the basis of the literature of the subject and confirmed factors. In the final phase, the extracted model was validated under the employment of the fuzzy interference method and the MATLAB software. Also, in terms of purpose, considering the viability of the results and the special nanotechnology development, staff and companies are active and the nanotechnology field this research is of a practical type. Since the purpose of the study is to obtain a model for accomplishing research and development activities. By considering the unanimity of a group of professors and experts in the field of nanotechnology, the proposed methodology is a development methodology and our research is indeed of survey research type.

3.1. Administrative model of the study

Considering what was mentioned in the previous section, the administrative model of the inquiry can be described in Figure 2.

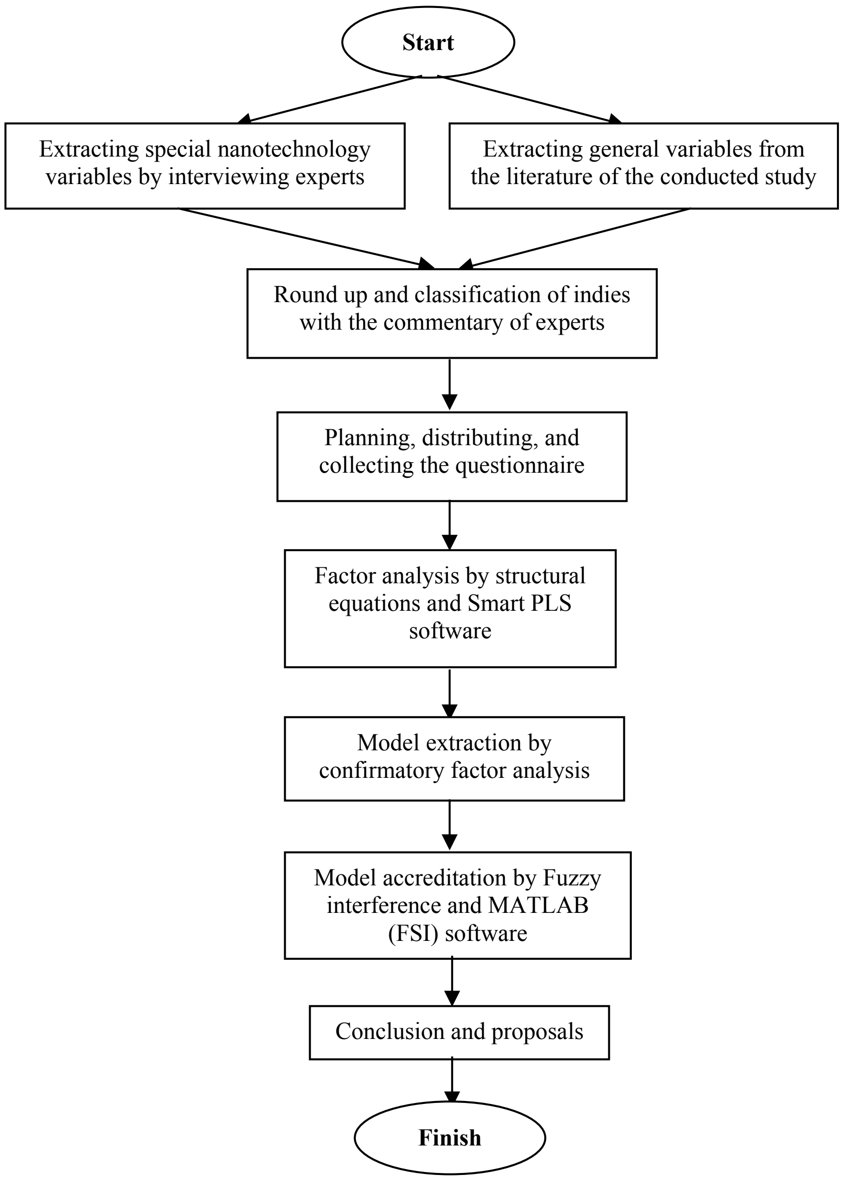


Figure 2. Executive model

3.2. Methods and tools of data collection

In order to collect data in this study besides library studies, interview with experts, field investigations, and collection of information using a questionnaire were conducted. The most important methods of data collection are given below:

Library studies: In this section, librarian sources, Farsi and English articles as well as books that are relevant to the subject of inquiry and some related websites were employed in order to collect information in the field of theoretical basis and the literature of the subject of inquiry.

Field researches: Considering that the purpose of this research is to study the effect of research and development activities and NanoFab centers on the development of the product in nanotechnology, a narrow rationalist viewpoint cannot be the loan basis of research. Hence, the compound quantitative and qualitative approach was added to the work formula. First of all, in this research, the viewpoint of experts that was obtained by interviews in terms of factors and indices related to the subject of research, which was extracted by librarian studies, was improved and confirmed. At the next stage, a questionnaire was employed to collect information.

Questionnaire: The type and nature of this study were added to the questionnaires or conducted as explained below. Data collection was achieved through the use of mansion questionnaires. The first questionnaire computed the effect level of each index related to research factor and the second questionnaire determined the function level of each of the mentioned indices in the field of nanotechnology. According to these two questionnaires, 22 indices were distributed in the form of five factors within the intended sample and the respondents assessed the indices.

3.3. Statistical population and determination of research sample size

In this study, limitation of access to experts and the low possibility of their response determine the statistical population; in this state, judgment sampling can be used to determine the sample size.

Judgment sampling is the choosing of test subjects that are highly qualified to provide necessary information and it is used when a limited category of individuals has the intended information within grasp. The statistical population of this research is composed of special staff managers of nanotechnology development, president and managers of Nano companies who possessed experience and research and development activities and product development. Thus, employing the judgment sampling method and number of 32 individuals were selected as sample size with the two following characteristics:

1. Experts and managers of nanotechnology development staff holding Master's or higher degrees in education with over 5 years of occupational proceedings and being familiar with nano companies' research and development activities.

2. Managers of nano companies with an age rank higher than 5 years possessing experience and research and development activities and product development.

Table 3 shows the information on the indices of population description of sample size.

Table 3. Population properties of the respondents

Education	Master's degree 62 %	Doctorates 38 %
Sex	Male 75 %	Female 25 %
Occupation	Nano staff managers 21 %	Nano company managers 79 %
Occupational precedence	Over 5 years	

3.4. Conceptual model of the study

Figure 3 shows the conceptual model, which is the outcome of literature review and variable effects of the study on each other.

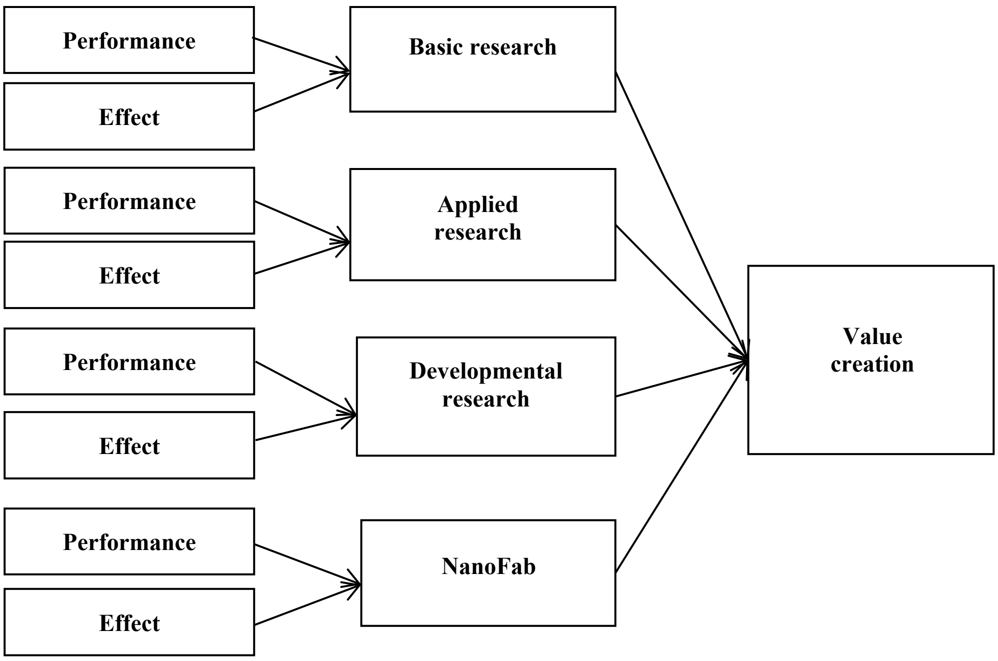


Figure 3. Conceptual model of research

3.5. Methods and tools of data analysis

In this inquiry, the results obtained from the questionnaire are classified and rounded up. Necessary diagrams are drawn based on descriptive statistics. To this end, task Exel and SPSS software were put to use. Moreover, to assess the stability of the questionnaire, Cronbach's alpha coefficient in the SPSS software was used. In the following, to obtain the final model of the research and its fitting, the smart PLS 3 software was employed to perform confirmatory factor analysis with the purpose of confirming the construct of research factors, and the integrity of the buoys used in the questionnaire should be ensured to measure the relevant variable. Finally, MATLAB was employed in conjunction with the fuzzy interference technique for fitting the conceptual model of the research and measuring the degree of the effects of independent variables on dependent variables.

4. FINDINGS

4.1. Standard coefficient estimation test

Figure 4 shows the number of factor loads of the research variables and also the measures related to each factor that also shows the estimation of factor loads with standard coefficients.

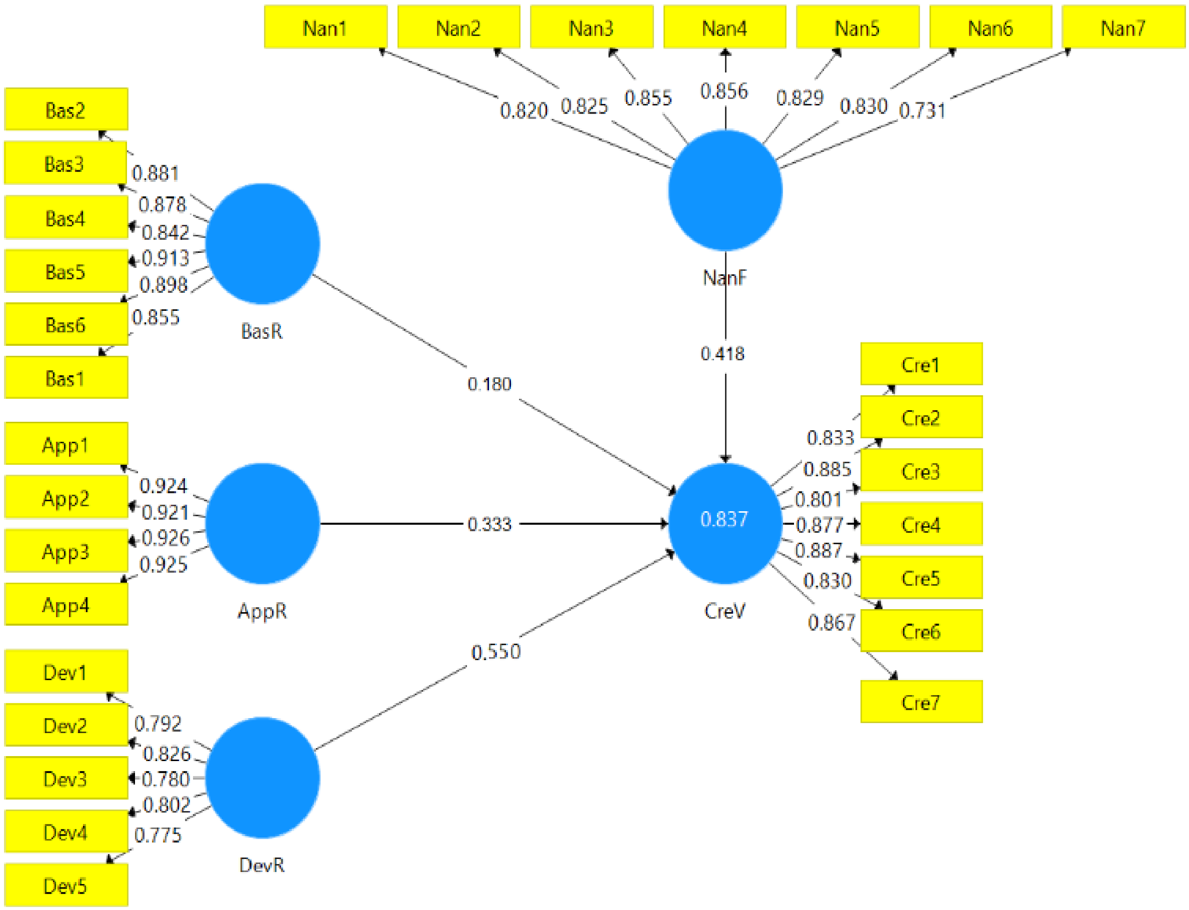


Figure 4. Measurement model in the standard coefficient estimation state (factor load)

4.2. Structural model analysis

Path analysis is a statistical method that uses standard multivariate regression coefficients in structural models and aims to gain quantitative estimates of the causal relationships between a set of variables. Table 4 presents the influence rate of each research factor on value creation.

Table 4. Path coefficients of research factors in factor analysis

Factors affecting product development and value creation from R&D activities in nanotechnology	Path coefficient
Basic research	0.18
Applied research	0.333
Developmental research	0.55
NanoFabs	0.418

4.3. Design of a fuzzy inference system

Fuzzy logic presents a method that is possible to use a broad variety of information, objective data, quantitative information, opinions, and subjective judgments to describe phenomena [39]. Fuzzy inference system is one of the most effective tools used in situations where we use the knowledge of experts. In a fuzzy inference system, researchers can identify and predict the relationships between variables based on fuzzy logic and the available basic and limited information on a phenomenon [40]. In fuzzy inference systems, experts are consulted to receive their expert opinions on model variables in the form of a set of fuzzy if-then rules. This set operates as an inference engine and combines the inputs of this system based on this inference engine, leading to the mapping of the input space to the output space.

4.3.1. Fuzzy sets

Fuzzy sets represent a mathematical method to express linguistic variables. Fuzzy set theory can express many concepts and expressions in mathematical language and provide the basis for reasoning, inference, control, and decision-making in conditions of uncertainty. According to fuzzy logic, definition words including low, medium, high or bad, good, excellent, etc. are interpreted to certain defined numbers.

4.3.2. Defining the membership functions for the input and output variables

A set of membership degrees of the members of a fuzzy set such as A is called the membership function of the set A. The membership function is a mapping of the members of the set A in the range of [0,1] so that A: y →[1,0]. In general, this type of mapping can be considered as a membership function of fuzzy collection and fuzzy systems; triangular, trapezium, Gaussian, belle shirt, ring-shaped, and left and right membership functions are a few to mention. Triangular and trapezium membership functions are very versatile because of the simplicity of their theorem and optimality of conclusions. These membership functions are linear, but the other mentioned membership functions are described as nonlinear membership functions. In this study, the triangular membership function is used.

Figure 5 shows the triangular fuzzy number. The parameters m, l, and u indicate the lowest possible value, the highest expected value, and the largest possible value in order to describe a fuzzy number, respectively.

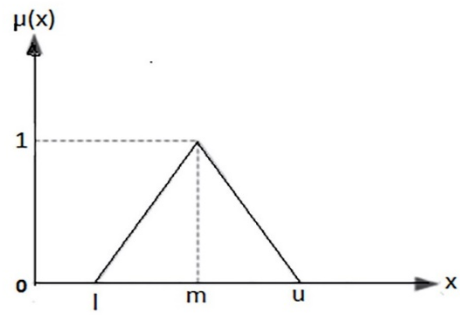


Figure 5. Fuzzy triangular number

4.3.3. Designing the system input component (Sub-FIS)

The independent variables are influenced by two inputs: the influence rate and the performance rate. Hence, they create the sub-FIS of the system. Figure 6 presents four system inputs.

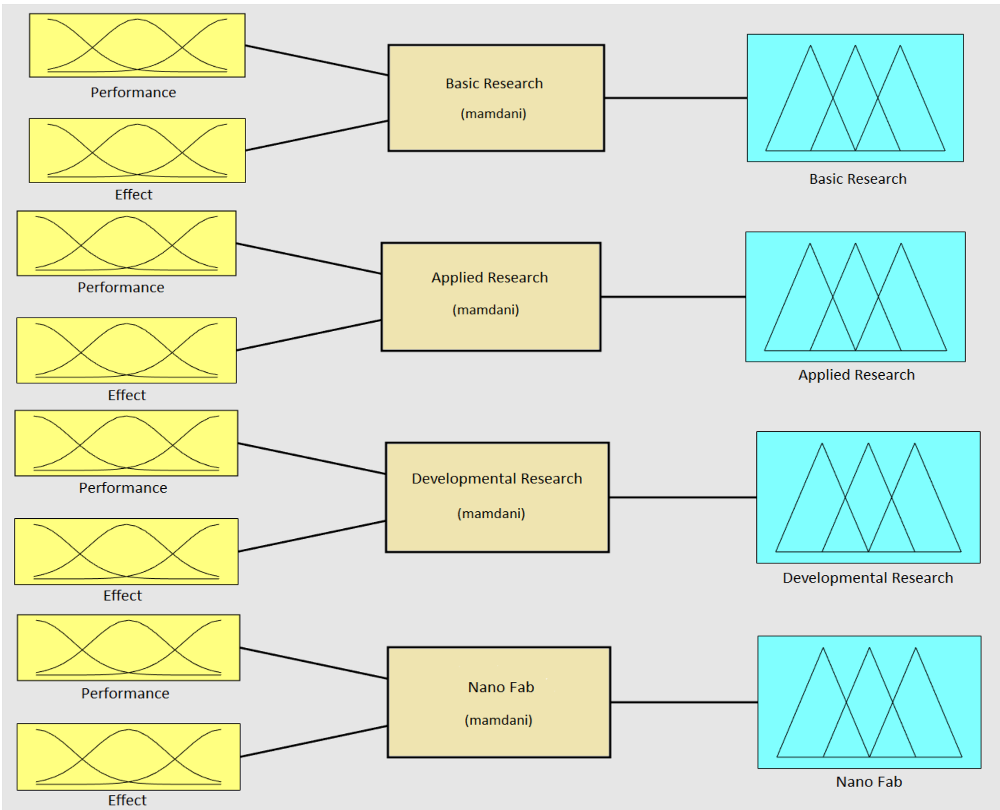


Figure 6. System input components

4.3.4. Fuzzy value of variables for Sub-FISs

Language variables including the influence and performance of each independent variable on the dependent variables have been predicted based on the questionnaire. Accordingly, it is required to determine the mathematical fuzzy value equivalent to the language variables. Table 5 shows this equivalence.

Table 5. Fuzzy value of language variables

Linguistic variables of performance (input)	Linguistic variables of effect (input)	Linguistic variables of factors (output)	Definition interval (Mathematical fuzzy value)
Very weak	Very low	Attenuation	(1,4)
Weak	Low	Shortage	(2.5,5.5)
Medium	Medium	Balance	(4,7)
Well	High	Adequate	(5.5,8.5)
Very well	Very high	Affluence	(7,10)

It is possible to draw the membership functions for the Sub-FISs according to the mathematical fuzzy value defined in Table 5. Figure 7 presents the drawing of membership functions for Sub-FIS.

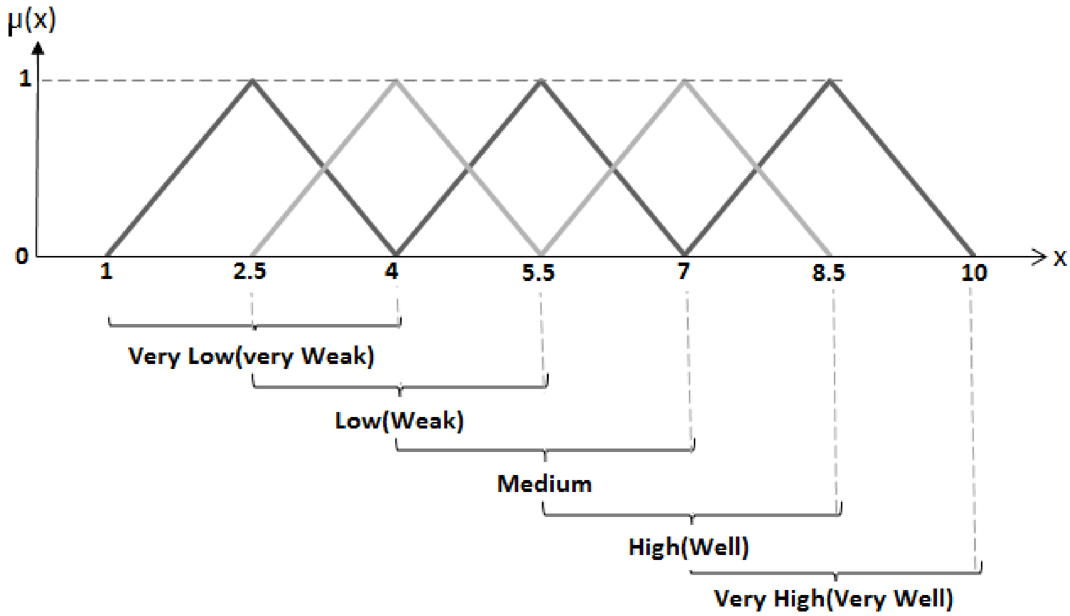


Figure 7. Sub-FIS membership functions

4.3.5. Structuring fuzzy inference rules

The most significant part of a fuzzy system is its rule base. This database is a set of logical if-then rules that result in mapping input variables to output variables. In the present study, inferential rules were designed based on experts' knowledge and interviews in the field of nanotechnology. Each factor in this study including basic, applied, developmental research, and NanoFabs was evaluated in terms of effect rate and performance rate and then, the inference rules of output were expressed with different input combinations. Table 6 summarizes the fuzzy inference rules for Sub-FISs.

4.4. Designing the key components of value creation of R&D results

In fact, the output of the models of the previous stages (Sub-FISs) is the input of this stage in the main FIS. Figure 8 shows the overall designed fuzzy system related to the value creation of R&D results.

Table 6. Rules of fuzzy inference research

Effect	**High and Very high**	Attenuation [1]	Shortage [2]	Balance [3]
	Medium	Shortage	Balance	Adequate [4]
	Low and Very low	Balance	Adequate	Affluence [5]
		Weak and Very weak	**Medium**	**Well and Very well**
		Performance		

1- It should have special support to correct the input-output in the "attenuated" state.
2- It must be amplified in the "shortage" state for the input-output modifying.
3- The input does not need to be modified in the "balance" mode.
4- The input should not be amplified in the case of "adequate".
5- The input should not be completely amplified in the case of "affluence".

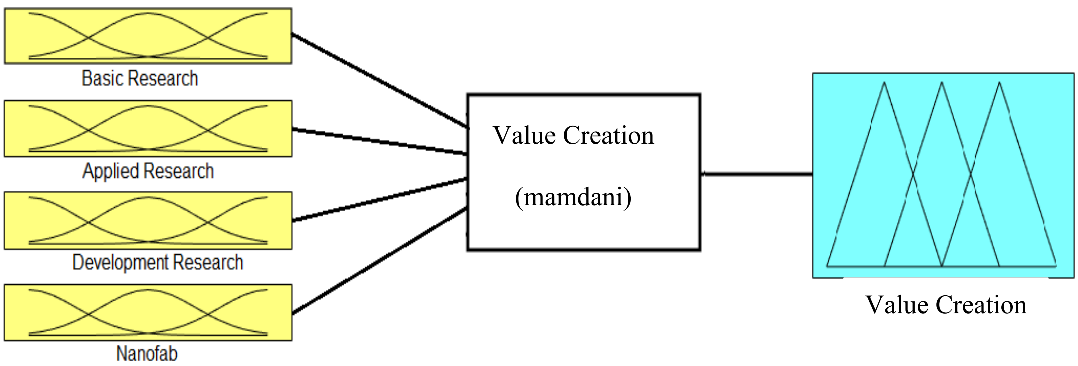


Figure 8. Key factors in creating value from R&D results

4.4.1. Fuzzy value of the main FIS variables

Table 7 shows the fuzzy values of the linguistic variables for the main inference system with triangular membership functions.

4.5. Implementing the fuzzy inference mathematical model

Table 8 presents the results of implementing the mathematical model in the Sub-FISs.

Table 7. Fuzzy values of Linguistic variables for the original FIS

Linguistic variables of factors (input)	Value creation linguistic variable (output)	Definition interval (Mathematical fuzzy value)
undesirable	undesirable	(1,6)
desirable	desirable	(4,8)
excellent	excellent	(6,8)

Table 8. Results of implementing the mathematical model for Sub-FISs

	Basic research	Applied research	Developmental research	NanoFabs centers
Performance	7.1	3.4	3.3	2.1
Effect	3.2	5.2	7.2	6.8
Result	7.43	4.4	3.23	1.38

The output of these Sub-FISs is applied as the main FIS input to evaluate the value creation of R&D activities after implementing Sub-FISs. Table 9 indicates the values of these inputs and outputs in the main model. In addition, Figure 9 shows these results including an image of the original FIS rules database. A fuzzy interference system generates the output by receiving input using rule-based interference motors and other parts of fuzzy systems such as fuzz makers and non-fozzmakers. Fuzzy rules are the phrases with a fuzzy if-then construct in which each of these compounds affecting the rules of indices is determined. Using the graphic section of fuzzy logic in MATLAB software, Figure 9 shows the schematic presentation of a fuzzy interference with a triangular membership function for the four inputs of fundamental research with a value of 7.43, functional research with a value of 4.4, developmental research with a value of 3.23, and NanoFab centers with a value of 1.38. The output of the system (value creation) is an equivalent of 3.71.

Obviously, value creation performance of R&D activities was estimated at 3.71, being in the undesirable range. Figures 10-A to 10-C show three curves of factors effective in the value creation of R&D activities. The inputs were compared with each other in pairs in each of these curves and their influence on the level of value creation performance of R&D activities was shown.

Figure 11 shows the results of implementing the mathematical model in the fuzzy inference system.

Table 9. FIS input and output values related to value creation performance of R&D activities

Basic research	Applied rresearch	Developmental research	Centers of NanoFabs	Value creation
7.43	4.4	3.23	1.38	3.71

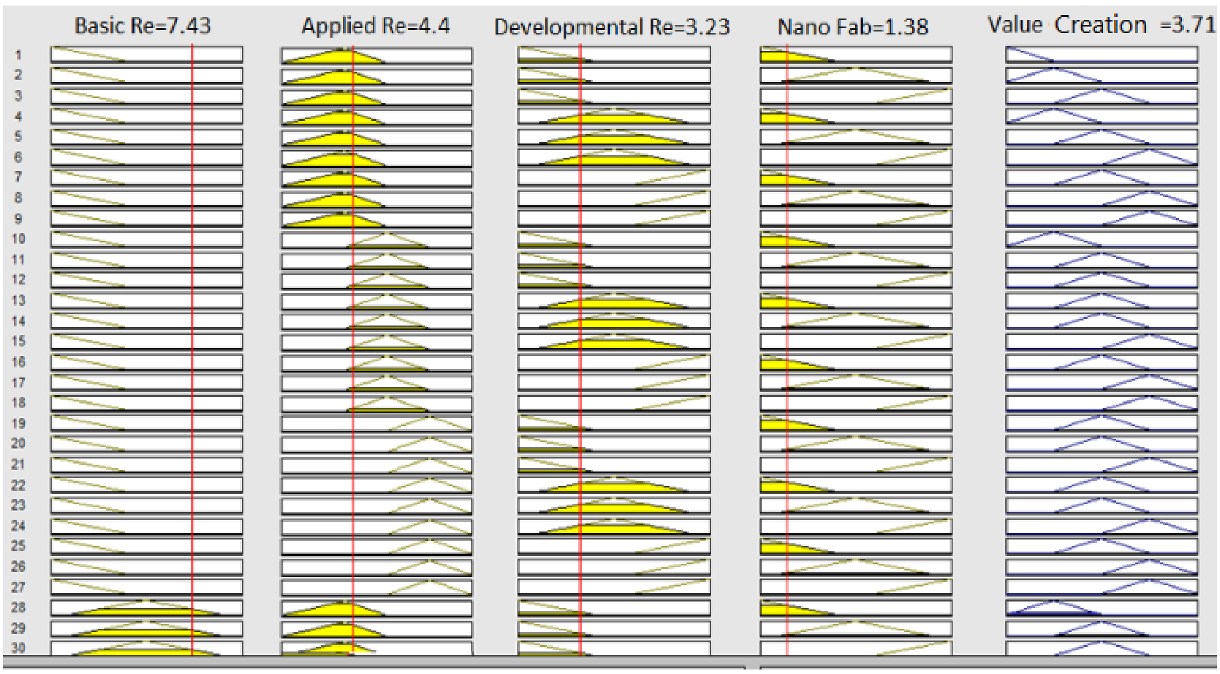
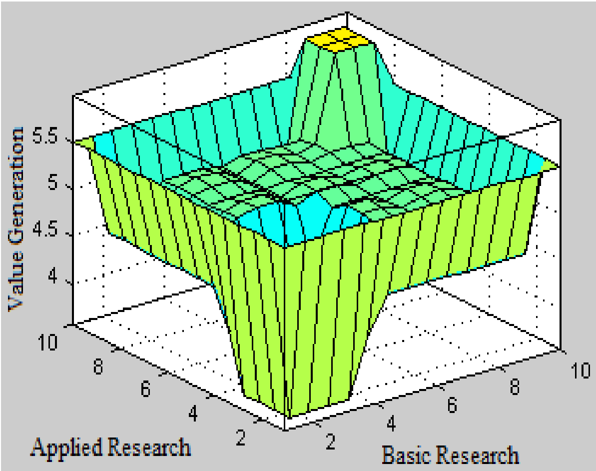
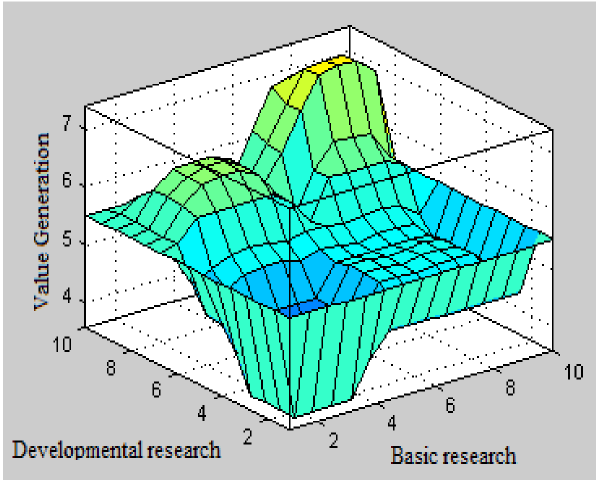


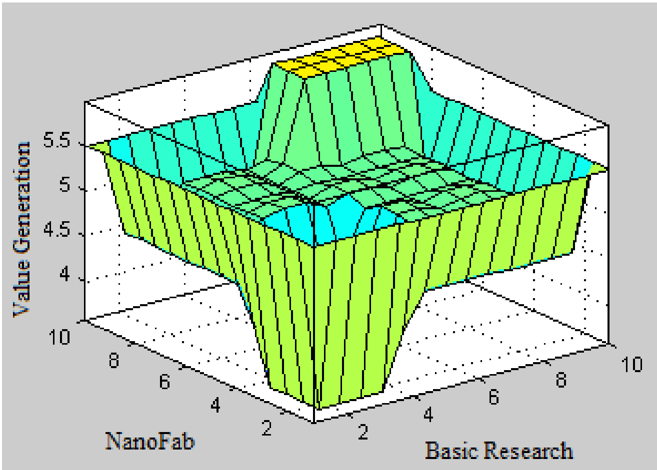
Figure 9. Value creation rules database of R&D activities



(a)



(b)



(c)

Figure 10. a) Influence curve of applied and basic research on output, b) Influence curve of developmental and basic research on output, c) Influence curve of NanoFab and basic research on output

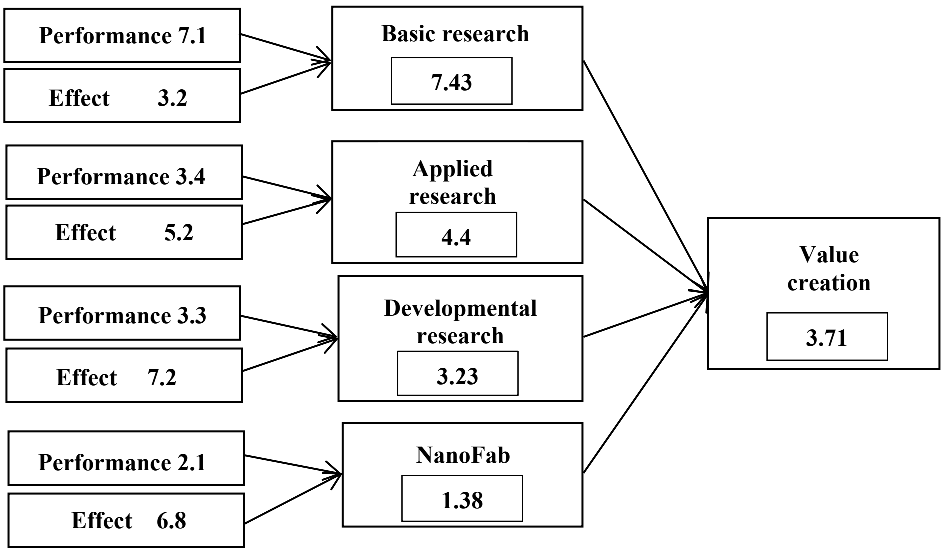


Figure 11. Implementation results of the mathematical model

5. DISCUSSION AND CONCLUSIONS

It is required to determine the position of each of the system inputs to analyze the results, according to Table 6, which is actually a fuzzy map of the rules expressed for the system. Based on the results, Table 10 shows the position of the inputs. As observed earlier, none of the inputs are in the balance state.

In the following, the status of each of the inputs is examined according to their position in Table 10 as well as the extent of their impact and performance on the output.

Table 10. State of system inputs according to performance and its influence rate on output

Effect	**High and Very high**	Attenuation (Development Research) (NanoFab)	Shortage	Balance
	Medium	Shortage (Applied Research)	Balance	Adequate
	Low and Very low	Balance	Adequate	Affluence (Fundamental Research)
		Weak and Very weak	**Medium**	**Well and Very well**
		Performance		

Fundamental research: Fundamental research is in affluence position, indicating that input should not be reinforced. Fundamental research with the score 3.2 is in the fourth rank in terms of the impact on the output, and it affects the output insignificantly among the various inputs of the system while it has the highest performance and has the score 7.1. It is possible to attribute this issue to Iran's high ranking in publishing scientific articles in nanotechnology.

Applied research: Applied research is in a shortage state, indicating that the input should be amplified to modify the output. Applied research with a score of 5.2 is in the medium state and the third place in terms of influence on the output; however, it is in the weak zone with the score 3.4 in terms of performance.

Developmental research: Developmental research is in the weakened position, indicating that input should be supported to modify the output. Developmental research with the score of 7.2 is in the high state and ranks first in terms of influence on output, but it is in the weak zone with the score of 3.3 in terms of performance.

NanoFab: NanoFab is in a weakened state indicating that the input needs particular support in order to modify the output. NanoFab with the score of 6.8 is in the second place in terms of influence on the output, but it is in a very weak area in terms of performance with score of 2.1.

Examination of these results and Figure 11 helps understand that fundamental research is one of the strengths of nanotechnology research and development activities; however, the applied development research and activities related to NanoFab centers are the weaknesses of research and development activities in nanotechnology. Of course, these strengths and weaknesses are not the same in all of these sections. Table 11 indicates the performance of each of the research factors based on Figure 11.

Table 11. The performance rate of research factors

Factors affecting the value creation of R&D activities in nanotechnology	Performance rate	Linguistic variables
Basic research	7.1	Well
Applied research	3.4	Weak
Developmental research	3.3	Weak
NanoFabs	2.1	Very weak

6. RESULTS AND FINDINGS ACHIEVED BY RESEARCH QUESTIONS

1-Why do the industrial sector fail to use the results of academic research in order to develop products and create value in the field of nanotechnology?

In this study, four factors are identified as influential and causal factors in creating value from R&D results in nanotechnology, which are fundamental (academic), applied, developmental research and intermediate research centers, or NanoFabs. Academic research has the least influence on R&D results among these factors; therefore, it is possible to expect that value creation indices such as new product production or product quality are to be improved and in fact, the industry can use academic research because of the good scientific position in the field of nanotechnology and good performance in this factor. However, the weakness in the performance of the two factors of development research and NanoFabs as the two factors that have the highest influence on the value creation of R&D activities in nanotechnology is the most significant issue. Although establishing the NanoFab centers has a more limited influence on output than development research and is in the second place among these two factors, as an intermediate research center, it is a bridge between fundamental research in the university and development research in industry; consequently, it is possible to state that the industry sector does not use academic research which is due to the lack of NanoFab research centers. It can be concluded that in the field of renewable energy, according to the role of nanomaterial in improving the efficiency of renewable energy systems, creating NanoFab or NanoFabs focusing on the development of nanomaterial can significantly affect the development of renewable energy.

In fact, the main reason as to why the industry section is unable to use university researches for the product development is that the mentioned researchers are mostly engaged with basic scientific development. However, what is needed in the industry for product development is the knowledge of engineering and programming the way to exploit different types of science in actual environments, not a type of knowledge that is developed in scientific and laboratorial environments. In addition, what can make university researches applicable to the industry is filled researches which are done through NanoFabs in nanotechnology. In fact, the NanoFabs are the intermediate circle between university researches and developmental researches in the industry, and the industrial section is unable to utilize university resources for product development until NanoFabs are made.

2-What are the strengths and weaknesses of research and development activities in nanotechnology?

Figure 9 shows the status of the inputs of the fuzzy inference system (research factors) considering their performance and influence on the output, helping recognize that fundamental research is one of the strengths of research and development activities in nanotechnology. However, applied, development research, and also activities related to NanoFab centers are the weaknesses of research and development activities in nanotechnology. Of course, all these sectors do not have the same strength and weaknesses. In fact, analysis of the performance of the factors influencing the value creation of R&D activities in nanotechnology allows recognizing that the factors with the greatest influence on output, such as developmental research and NanoFab centers, have the lowest performance, while fundamental research has the highest performance with the least influence on the output. Accordingly, it is possible to consider this imbalance between the influence of a factor and the performance of that factor as the main weakness in the system of R&D activities in nanotechnology.

Considering the conclusions made within by this study, it can be acknowledged that due to the gap between basic research conducted in universities and development research conducted in industry. The industry sector can not use the research done in universities to develop the product. But the results of applied research in NanoFabs that lead to the production of prototypes can be used to develop a product in the industry. Therefore, to create a bridge between the university and industry, there is no other way but to create an intermediate research center called NanoFab. NanoFab acts as a link between academic research and developmental research.

7. ACKNOWLEDGEMENT

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NOMENCLATURE

RERs	Renewable Energy Resources
RES	Renewable Energy Sources
NanoFab	Nanofabrication
RTO	Research & Technology Organization
NNFC	National NanoFab Center
CNSNT	Center for Nano Science and Nanotechnology
CNT	Carbon Nanotube
PV	Photovoltaic
NNI	National Nanotechnology Initiative
INIC	Iran Nanotechnology Innovation Council

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