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Research and Development Capabilities: Iranian Auto Industry

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ABSTRACT

Experience has shown that in successful developing countries, R&D is the main key to any kind of development. Imported technologies and R&D have important roles in the development of local technologies. According to studies in the field of technology capabilities we identified the most important indicators to evaluate the level of R&D capabilities. Since the technological development correlates with the level of R&D capabilities, trying to promote its key importance. So, to develop and apply new technologies, we must first evaluate the existing capabilities and Based on the capabilities and opportunities choose proper strategies. In this research by using FDM, the right combination of R&D capabilities indicators relating to the auto industry is presented. We have analyzed 125 companies in auto industry and determined R&D capabilities of each level. The results show that half of the surveyed companies had R&D capabilities in Level 1 and 2 or in other words very low level of R&D capabilities.
KEY WORDS: Developing Countries, R&D capabilities, technology capabilities, auto industry

INTRODUCTION

In successful developing countries, experience has shown that R&D is the main key for any kind of development, because R&D affects efficiency and proficiency in every field more than anything else [1].Generally, importance of technology in today's world can be said in this way: first, technology is the basis for achieving success in business[2], producing products [3] and a variety of services[4] and without effective usage of technology, we cannot put ourselves in a competitive position[6]. Secondly technological innovations are the only way for achieving a long term development [7]. Import technology and R&D has an important role in the development of local technology [4,7,10]. Many developing countries focus on developing their industry's technological capabilities through the process of technology transfer [7,11,12,13]. In order for companies to achieve the goal of successful technology Capabilities development, they must find out what the key concepts and possible factors affecting that goal are. R&D Capabilities plays a crucial role in Promoting technology capabilities, in domestic and international market [15, 16]. Technology transfer and its development by using R&D is the main key for success in increasing technology capabilities, but it is not enough. Factors such as efficiency of selected technology, technological transformations are also important [14, 19]. Technology assessment is a tool [18], which helps understanding the technology and making decision about it [21]. Therefore, to develop and apply new technologies must first evaluate the existing capabilities and Based on the capabilities and opportunities; choose proper strategies [22]. Since the technology development correlates with the level of R&D capabilities, trying to promote it is the main importance [2; 14; 18].The R&D roles on the auto industry in some countries can be observed in different studies. Among them are the studies by Walsh et al (1994) on the European[2], Mc Alinden et al.(2008) on the Latin American[6], Smitka et al.(1991) on the Southeast Asia[23], Paul and Speece (2003) an empirical study in the Thai auto industry[27], Rodriguez and Arbix(2000) on the auto industry of Brazilin [28] and Liu and Tylecote (2006) three Case Studies in the Chinese Auto Industry[29]. The major findings are as following: The role of R&D in product innovation [2, 6]; Smitka et al., (1991), R&D strategies [23, 27], R&D networking [26, 27, 28], and R&D structures [2, 6 , 26, 29].The auto industry is regarded as the biggest part of the global production and today, it is perceived to be the driving force for other industries. As a resulted in some developing countries, special attempts to promote technology policies for auto industry are made. The development of Iranian auto industry, can be divided into four periods [30].

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Table 1.Characteristics of Iranian auto industry

Periods	Characteristics of Iranian auto industry
Period I (1960-1990)	• Vehicle assembler under foreign licenses. • Limitedly began with a low level of local Content by the state company
Period II (1990-1995)	• Creating Capabilities for manufacturing and products with foreign brands. • Moving it to the level of manufacturing separate parts with a higher local content.
Period III (1995-2000)	• Supplying networking policies in order to increase level of local Content and increased quality. • Mass production. • Entry of private firms was encouraged for the manufacturing of luxury vehicles.
Period IV (From 2000)	• Development of the auto industry was aimed at designing national vehicles with the assistance of foreign partners. • Diversifying the products aimed at satisfying the local customer and Entry to global markets and limit exports.

Most of the vehicles produced in Iran are made by Iran Khodro company (Partner of the French Peugeot) and Saipa company (Partner of the Korean KIA Motors). These two companies held a market share of above 94% of vehicles in 2013, with a production of 1.4 million vehicles (Annual Report Iran's Ministry of Industry, 2013). Iran Khodro Company exported 43,000 vehicles in 2008(Annual Report Iran's Ministry of Industry, 2009). The rest of the vehicles produced were shared by seven private automakers. technological capabilities promotions and competencies in the automotive industry in Iran in year 2024 are envisioned, which includes: (Systematic relationship with the automobile industry especially in the field of new technologies and lead to sustainable development (environment-friendly, recyclable materials, fuel-efficient vehicles, electric, hybrid), Development of science and technology parks, Development of engineering and consulting services and Development and professional societies(Report Iran's Ministry of Industry, 2014). Efficiency in setting up, operating, diversifying, and expanding an industrial operation requires specific knowledge [40, 47] and skills in technology [3, 4, 7], that are called "Technology capabilities" of the firm. Technology capability has been viewed as the combination of resources and processes which can be developed, deployed and protected for managing technology [3, 40]. Technological Capabilities are examined here from the perspective of Lall's (1991) defining a complex array of skills, technological knowledge, and organizational structures, require operating technology efficiently and accomplishing processes of technological change [22]. Technological effort seems to be essential for firms' performance, starting from investment, production or linkages, as suggested by Lall's taxonomy. This means that firms should have their own capabilities required for the various activities from setting up to operating an enterprise. The Lall taxonomy of technological capabilities has been successfully used by case study research to assess levels of firm-level technological development in developing countries [35, 37, 40]. Rush et al. (2007) presented a tool having nine dimensions to evaluate and measure technology management capabilities of a firm [7]. APCTT (1989) has a method for technology capability assessment with four dimensions that include Technoware ,Infoware, Humanware, Orgaware [39]. Chiesa et al. (2008) considers the technology assessment and selection in the process of technology strategy and R&D strategy [19]. The independent variables however, consist of firm's R&D spending; firm's planning and control of the technology acquisition; availability of technical personnel; duration of training programs; government role and mode of transfer used [33, 41,42] . Different reasons for the necessity of this research are: In most of the researches only one known model is used to evaluate the level of technological capacity of a company and R&D Capabilities. We find very fewer studies directly related to R&D capabilities in the developing countries and auto industry. This research is significant in two dimensions; first, with a review of existing models, a hybrid model for assessing the level of R&D capabilities is designed. Second, this research methodology is new because in this study a quantity group decision making for designing a propose model will be used and this model can also will be used in other areas. Then, according to studies in the field of technology capabilities we identify the most important indicators to evaluate the level of R&D capabilities. Then, by using fuzzy Delphi method, the right combination of R&D capabilities indicators will be presented. Finally, the modeling of a fuzzy expert system to determine the level of R&D capabilities, 125 companies in auto industry are analyzed, and determined R&D capabilities of each level. According to the literature review we identified 11 indexes that are in direct contact with the capabilities of R&D, especially in the auto industry. These indexes include: Ability to identify scientific principles in Technology, Ability to build laboratory made prototype , Ability to build an operational prototyping, Ability in conceptual modeling , Ability to generate ideas in technology , Research Ability, Applied Research Ability, The complexity of human skills, Development Ability, Simulation Ability, Ability to attract and apply technology. In the figure below we can see the Framework of research methodology.

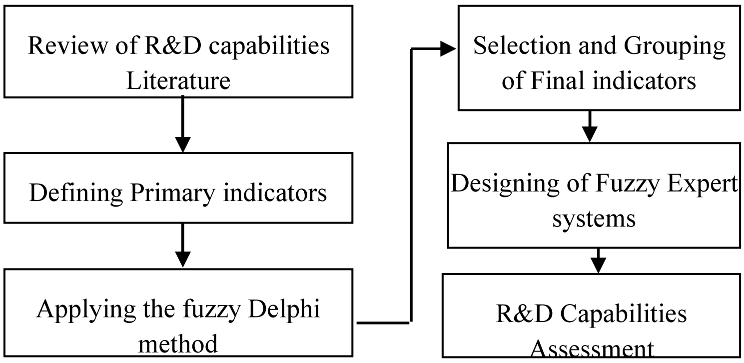

Figure 1.Framework of research methodology

RESEARCH METHODOLOGY

This study provides a model for assessing the level of R&D capabilities of the two phases. First, according to the indicators identified in the literature review, using fuzzy Delphi method, the experts agreed that parameters can be extracted. In this research, experts including specialists in the auto industry are the Technology experts. The survey has been used for 11 individuals [56]. Classical random sampling method was used in this research. The sampling units in the population studied class of adjectives that are homogeneous variables, grouped, so that changes within groups is lower [54]. Number of samples for this research will be 125 companies. Field of company activity indicators has been divided into four categories, Suspension group, Electrical group, Engine and power groups and Trims group. Finally,. The goal of fuzzy Delphi method is to reach an agreement amongst a group of experts regarding a certain subject by using questionnaires and surveys repeatedly and considering their feedback. Delphi method was used in different fields such as anticipation and determination. As mentioned, survey is to acquire expert opinion about effects of known indicators. Therefor this quantities "scale" is expressed by experts using variables. Using variables of a certain quality proves to be problematic when it comes to experts expressing their views. But by defining qualitative variables, experts will respond to the question with equal mentality. The survey is designed regarding suggested indicators and variable definition. At this point experts are asked to choose the degree of effectiveness of each indicator in R&D Capabilities evaluation in Auto industry that is defined as qualitative options. Average effectiveness of each indicator in R&D Capabilities evaluation is calculated based on following relations [49]. In relation above $A^{(i)}$ indicates it's expert perspective and A_m indicates average expert perspectives.

$$A^{(i)} = \left(a_1^i, a_2^i, a_3^i\right), \qquad i = 1,2,3,\ldots,n \qquad (1)$$

$$A_m = \left(a_{m1}^i, a_{m2}^i, a_{m3}^i\right) = \left(\tfrac{1}{n}\sum a_1^{(i)}, \tfrac{1}{n}\sum a_2^{(i)}, \tfrac{1}{n}\sum a_3^{(i)}\right) \qquad (2)$$

In this research, average value method is used. In this method left and right separation, which in addition to being simple uses all information regarding membership submission, for defuzzy. The amount of defuzzy using average quantity method equals with:

$$S(A) = 1/2(S_L(A) + S_R(A)) \qquad (3)$$

$$S(A) = 1/2\left[(a_{2i} - \int_{a_{1i}}^{a_{2i}} f_{\bar{A}}(x)) + (a_{2i} - \int_{a_{2i}}^{a_{3i}} f_{\bar{A}}(x)) + \right] = \frac{a_{1i} + 2a_{2i} + a_{3i}}{4} \qquad (4)$$

Table 2.The results of the first round of the fuzzy Delphi method

Defuzzy	Fuzzy numbers (First round)			Indicators	Row
	a_1	a_2	a_3		
7.41	5.64	7.64	8.73	Ability to identify scientific principles in Technology	1
7.23	5.45	7.45	8.55	Ability to build a laboratory prototype	2
7.41	5.82	7.64	8.55	Ability to build an operational prototype	3
7.77	6.00	8.00	9.09	Ability in conceptual modeling	4
6.41	4.55	6.55	8.00	Ability to generate ideas on technology	5
7.86	6.18	8.18	8.91	Research Ability	6
7.36	5.55	7.55	8.82	Applied Research Ability	7
7.14	5.27	7.27	8.73	The complexity of human skills	8
7.18	5.36	7.36	8.64	Development Ability	9
7.09	5.18	7.18	8.82	Simulation Ability	10
9.05	7.45	9.45	9.82	Ability to attract and apply technology	11

Expert disagreement can be calculated using relation (5) [16]. In fact based on this relation experts are able to compare their views to average perspectives, and if needed balance their prior perspectives. By using relation (3) expert views are calculated and therefore a survey can be designed. Then each of experts by reevaluating prior perspectives announces new views.

$$e = \left(a_{m1} - a_1^{(i)}, a_{m2} - a_2^{(i)}, a_{m3} - a_3^{(i)}\right)$$
$$= \left(\tfrac{1}{n}\sum a_1^{(i)} - a_1^i, \tfrac{1}{n}\sum a_2^{(i)} - a_2^i, \tfrac{1}{n}\sum a_3^{(i)} - a_3^i\right) \qquad (5)$$

Regarding first survey, in addition to closed questions, expert views are also acquired by using open questions, therefore after refining presented viewpoints and attending meetings with experts, guiding professors and counselors, following indicators were added to first conceptual model.

- Subset testing and evaluation
- Final product evaluation capability
- Technological cooperation with technological source capability
- Rapid model making capability

At this level by adding changes in indicators of the model considering points mentioned above, the second survey is designed and sent back to the expert group also each person's prior perspective and the extent of their disagreement with other experts were sent. Results are presented in table 3.

Table 3.The results of the second round of the fuzzy Delphi method

Defuzzy	Fuzzy numbers (second round)			Indicators	Row
	a_1	a_2	a_3		
7.59	5.82	7.82	8.91	Ability to identify scientific principles in Technology	1
7.00	5.18	7.18	8.45	Ability to build a laboratory prototype	2
7.95	6.18	8.18	9.27	Ability to build an operational prototype	3
7.55	5.73	7.73	9.00	Ability in conceptual modeling	4
6.27	4.27	6.27	8.27	Ability to generate ideas regarding technology	5
7.95	6.18	8.18	9.27	Research Ability	6
7.14	5.27	7.27	8.73	Applied Research Ability	7
6.95	5.09	7.09	8.55	The complexity of human skills	8
7.59	5.82	7.82	8.91	Development Ability	9
7.95	6.18	8.18	9.27	Simulation Ability	10
9.05	7.45	9.45	9.82	Ability to attract and apply technology	11
7.09	5.18	7.18	8.82	Ability to Test Details	12
7.95	6.18	8.18	9.27	Ability to Test final product	13
9.05	7.45	9.45	9.82	Ability of Technological collaboration	14
7.00	5.18	7.18	8.45	Rapid prototyping ability	15

Calculated as the main difference, two steps, 1 and 2, using the relations between fuzzy numbers (Equation 6) is calculated. If the calculated difference is less of 0.2, fuzzy Delphi process stops [49].

$$S(A_{m2}, A_{m1}) = \left|\frac{1}{3}\left[(a_{m21} + a_{m22} + a_{m23} +) - (a_{m11} + a_{m12} + a_{m13})\right]\right| \qquad (6)$$

According to equation 6, the difference between first and second phases of the table is as follows:

Table 4.Difference between the first and second rounds of expert opinion surveys

Difference	Second Round	First Round	Indicators	Row
0.18	7.59	7.41	Ability to identify scientific principles in Technology	1
0.23	7.00	7.23	Ability to build a laboratory prototype	2
0.55	7.95	7.41	Ability to build an operational prototyping	3
0.23	7.55	7.77	Ability in conceptual modeling	4
0.14	6.27	6.41	Ability to generate ideas regarding technology	5
0.09	7.95	7.86	Research Ability	6
0.23	7.14	7.36	Applied Research Ability	7
0.18	6.95	7.14	The complexity of human skills	8
0.41	7.59	7.18	Development Ability	9
0.86	7.95	7.09	Simulation Ability	10
0.00	9.05	9.05	Ability to attract and apply technology	11
-	7.09	-	Ability to Test Details	12
-	7.95	-	Ability to Test the final product	13
-	9.05	-	Ability of Technological collaboration	14
-	7.00	-	Ability of rapid prototyping	15

Mean differences were less than 0.2 are removed from the process. In addition to changes in model index, a third questionnaire was developed. The results are presented in Table 5.

Table 5.Difference between the second and third rounds of expert opinion surveys

Difference	Third Round	Second Round	Indicators	Row
0.14	7.14	7.00	Ability to build a laboratory prototype	1
0.00	7.95	7.95	Ability to build an operational prototyping	2
0.05	7.50	7.55	Ability in conceptual modeling	3
0.18	7.32	7.14	Applied Research Ability	4
0.18	7.77	7.59	Development Ability	5
0.09	8.05	7.95	Simulation Ability	6
0.05	7.14	7.09	Ability to Test Details	7
0.18	8.14	7.95	Ability to Test the final product	8
0.18	8.86	9.05	Ability of Technological collaboration	9
0.14	7.14	7.00	Ability of rapid prototyping	10

According to execution of this method, two indexes: ability to generate ideas regarding technology (value 6.27 in second round) and the complexity of human skills (6.95 in second round) were excluded and other indicators were assigned.

Design of a fuzzy expert system to evaluate the R&D capabilities Levels

Fuzzy Expert System provides a method for calculating the uncertain data [53, 54, 55, 56, 57]. Fuzzy Expert System By combining fuzzy set theory and fuzzy logic systems provide a framework for linguistic knowledge with uncertainty [55]. There are two main characteristic that makes them more popular: First, they are suitable for approximation reasoning, especially for systems that are difficult to extract a mathematical model form and one that, fuzzy logic allows decision making by using membership function, which are easily understandable by humans[56, 57]. In this section a complex of verbal terms are defined for each input variable. Their count is three terms per input parameter. Then by using expert perspectives in auto industry the amounts of these parameters were decided. After attaining results, average expert perspectives were transformed to triangular fuzzy numbers and used as an input for system, results can be seen in the following table.

Table 6. Membership function of the input of R&D

Fuzzy numbers	Linguistic Values	Variable name
[0 0 0.4]	Basic research	**Research capabilities**
[0.2 0.5 0.8]	Applied Research	
[0.6 1 1]	Advanced Research	
[0 0 0.4]	Modeling and Simulation	**Prototyping capabilities**
[0.2 0.5 0.8]	Laboratory prototypes	
[0.6 1 1]	Operational Prototypes	
[0 0 0.4]	low	**Rapid prototyping capabilities**
[0.2 0.5 0.8]	medium	
[0.6 1 1]	High	
[0 0 0.4]	Incomplete technology transfer	**Technology Development capabilities**
[0.2 0.5 0.8]	complete technology transfer	
[0.6 1 1]	Collaboration with technology resources	
[0 0 0.4]	Testing some subsets	**Tests capabilities**
[0.2 0.5 0.8]	Testing subsets	
[0.6 1 1]	Testing final product	

According to Input variables output variables are defined. Variable output are R&D capabilities levels and we defined five different levels according to the characteristics of each company's R&D. After attaining results, average expert perspectives were transformed to triangular Fuzzy numbers and used as an output for system results that can be seen in following table. This variables and their amounts are used in next step and Fuzzy knowledge base, in addition to that input and output verbal variables are shown in following illustration.

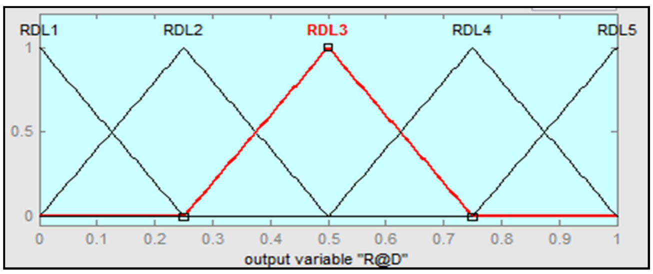

Figure 2. Membership function of the output of R&D

At this point, Knowledge base is made by input and output verbal variables and expert perspectives with 185 "if-then" rules. Knowledge base is a combination of expert perspectives of regarded field and verbal variable rules. These rules are used to express the relativity between input and output fuzzy complexes. Grammatical shape of a fuzzy rule is expressed in this way: if input conditions are proper then output results are inferable. Inference engine is the decision making unit in a fuzzy system. An inference engine is capable of inferring outputs by using rules and fuzzy operators meaning operators such as minimum and maximum or sum can be combined and fuzzy output is extracted from a complex of fuzzy input and fuzzy relations, by this, it can simulate a humanlike decision making ability . In this article Mamdani inference engine is used as the fuzzy system's core that by following relations, applies input usage process based on defined rules. After the model design and the definition of fuzzy rules based on the combination of 150 fuzzy inputs and output, Fuzzy Expert Decision System was developed to assess the level of R&D capabilities. In the following figure we see one of the output of the model include combine input variables on the level of R&D capabilities.

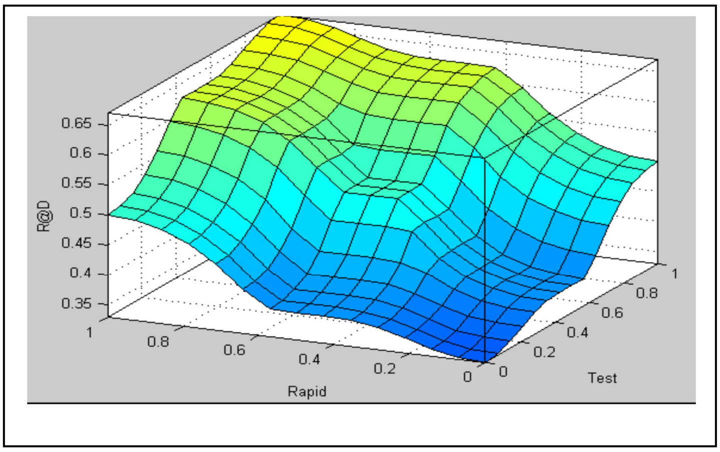

Figure 3. Surface of output R&D Capabilities

To check the reliability of the model 10 company case studies were conducted. According to the proposed model, the company's data in the field of research and development were analyzed. The results obtained from the applying the model was confirmed by experts.

CONCLUSIONS

In domestic and international market R&D Capabilities play a crucial role in Promoting technology capabilities [15, 16]. It is regarded as an important strategic resource, enabling new ventures to gain market acceptance and achieve long-term competitive advantage through continuous innovations and the introduction of new products [16, 14, 2]. Generally, advanced technology and new products and a quick response to changing market demands are the key characteristics of R&D Capabilities [17, 18, 19]. Entering global markets requires a Technology strategy codification which is considering the traits of industry and R&D Capabilities. Technology strategy codification is not possible without assessing and appointing the level of R&D Capabilities of the industry [19, 14]. In order to answer the key question of what factors in Iran as one of the developing countries is important for the evaluation of R&D capabilities, in the First step Primary factors are extracted from the literature study then using Fuzzy Delphi method five factors in the conceptual model were identified. Type of research, technology development capabilities, testing capabilities and capabilities in prototyping has been defined as a five decision variable in the evaluation of R&D. Then with modeling evaluation of R&D capabilities by using Fuzzy Expert System and check its reliability, five levels were determined to evaluate the performance of R&D. In order to survey Experts, a questionnaire was designed to measure each factor. According to the number of sample companies selected and results of the data analysis collected. By providing a model of a fuzzy expert system, 125 companies in the auto industry were analyzed. The following table shows the number of companies that are active in each different category.

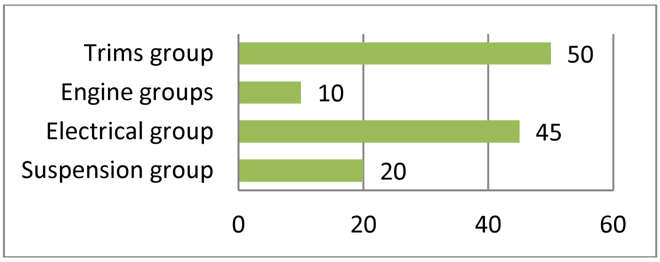

Figure 4. Number of samples and field of company activity

The results from the proposed expert system shows:

- R&D capabilities of the companies surveyed, 24% had very low level capabilities, 26% had low level capabilities, 38% had medium level capabilities, 9% had high level capabilities and 3% had very high level capabilities.
- Half of the surveyed companies have R&D capabilities in Level 1 and 2 or in other words very low and low level of R&D capabilities.
- Only 12 percent of the surveyed companies have R&D capabilities in Level 4 and 5 or in other words high and very high level of R&D capabilities.

Also as the most important factor in low level R & D capabilities, we can mention the following: Generally researches are conducted in basic level. Researchers conducted at an advanced level is very rare. Simulation and modeling capability is high. Prototyping capabilities in the operating environment are weak. Rapid prototyping is generally at an intermediate level. Failure in completing the transfer of technical knowledge, designing and manufacturing products from foreign sources and also inability to test components and the final test samples. According to the following figure shares of each the studied groups in the levels of R&D capabilities is observed.

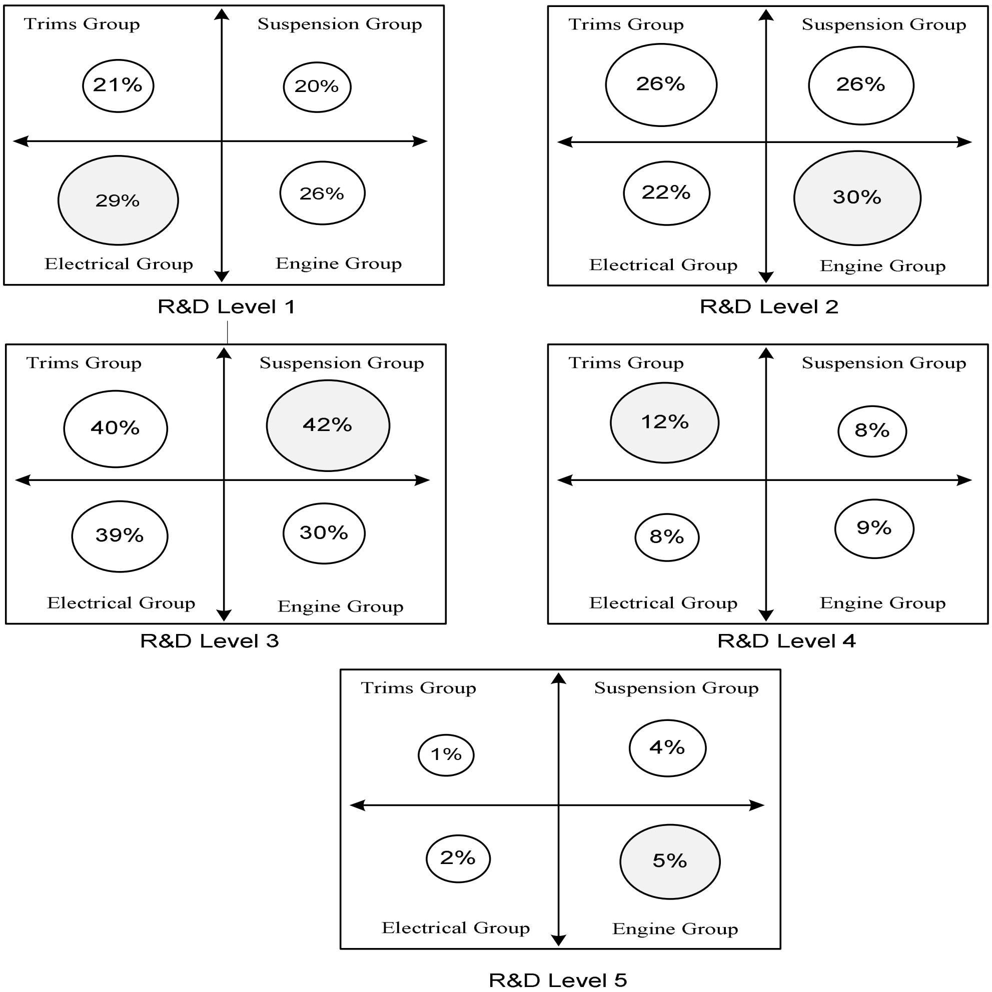

Figure 5.Shares studied groups in the levels of R&D capabilities.

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