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An Innovation Measurement Model Based on THIO Classification: An Automotive Case Study

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Abstract

Many criteria have been presented so far for innovation measurement. Presenting the relation between input and output of innovation, completing other criteria and achieving more comprehensive criteria has also been raised. What is of vital importance is the right utilization of these criteria towards measuring innovation. This paper seeks to present a model to measure innovation that, in addition to the simplicity of its perception and measurement method, has an adequate comprehensiveness. The analyses are undertaken through two real case studies in automotive industry in Iran. The results show that Saipa automotive company should concentrate on Info-ware, Orga-ware and Human-ware while Iran-khodro automotive company needs to focus on Info-ware, Orga-ware and Techno-ware aspects to balance the innovation processes.

***Keywords*:** THIO Model, Innovation measurement, Research and development, New Product development, Automobile industry.

1. Introduction

How can we manage things without measurement? We are fully aware that in current competitive atmosphere; Innovation is the sole provision of survival. But how can we mange and measure this costly process?
Unless you have a robust and strong Research and Development (R&D), there is no hope to develop a new product or process within a reasonable amount of time or with an appropriate cost. This is equivalent to inability in competition and elimination from market.
The traditional R&D performance measurement approach, addresses costs allocation and its amount (Financial-oriented measurement). Great deals of efforts have been made so far to obtain a univalent and homogenous policy to guarantee a proper pay-off in R&D department investment. As a matter of fact, innovation process and R&D productivity have to be accurately measured and determined respectively to adopt a commensurate policy and strategy. All these activities are subject to the proper innovation measurement (Terleckyj, 1974 and 1980).
Statistics of 90s indicate that not only investment on R&D has risen but also a certain amount of high-tech industries revenues have been allocated to this field. R&D investment growth have promoted to 80 percent in America and 450 percent in Japan since the beginning of 70s up to the midst of 90s (Suresh Kumar, 2000).
In this regard, Organization for Economic Co-Operation and Development (OECD) statistics have corroborated that aero space industries have allocated 20% of their revenues to invest on R&D and new product and process development.
In other industries, this percentage varies as follows:
Office and computing 17%, communication 10%, drugs and medicine5%, scientific instrument5%, electrical machinery 4%, motor vehicle 3% and chemicals 2.5% (OECD, Science, Technology and Industry Scoreboard, 1999 and OECD, Science, Technology and Industry Scoreboard, 2001)
In innovation measurement discussion, traditional methods have generally addressed the R&D data related cost analysis and patent data. Some other criteria have gradually been added to previous model to integrate and update previous ones (Flor & Oltra, 2004). What is of noticeable importance is to present a succinct but exhaustive model which is able to favorably cover presented criteria. Innovation measurement has greatly evolved and reached to a point that for each sector, appropriate indices have been presented. In a general classification, these criteria have been categorized as below:

1- Criteria based on innovation input
2- Criteria based on innovation output
3- The source of used information in innovation criteria.

And also innovation information resources are divided into two categories:

- Primary data
- Secondary data

Primary data are not available and must be obtained through research and investigation. However secondary data have already been collected and calculated for

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different purposes by various centers. Statistics, estimations, internal and international rankings belong to this group (Flor & Oltra, 2004).

It is worthwhile to mention that presented model in this paper tries to cover these classifications. In any case, the purpose of this paper is to present a transparent and exhaustive model based on THIO classification for manufacturing units (UNESCAP, 1989). In this way, the proposed innovation measurement model is applied for two real cases from the automotive industry, Siapa and Iran-khodro companies. Finally, by Radar charts the aspects that should be improved for an acceptable innovation level, can be determined.

2. Literature Review

According to Organization for Economic Co-Operation and Development (OECD, 2005), innovation, in general, is the implementation of a novel or drastically improved product, process, marketing or organizational methods in workplace organization, business practices, or external relations. Innovation is recognized as one of growth strategies to enter new markets, to increase market share and to provide the company with competitive edge.

This way, the issues of innovation, innovation management and innovation measurement have been studied from various aspects by academic researchers and practitioners. Zaltman & Dubois (1971) stated that the innovation concept can be defined from various viewpoints in academic researches such as functionally new, degree of acceptance within the relevant social system, effects upon established patterns of consumption or behavior, newness as perceived by an objective investigator, and newness as perceived by the relevant unit of adoption.

By reviewing the literature from the marketing, engineering, and new product development (NPD) viewpoints, Garcia and Calantone, (2002) indicated that it is important to consider both a marketing and technological perspective as well as a macro-level and micro-level perspective once identifying innovations. This way, they proposed a method for classifying innovations so that academics and practitioners can communicate with a common understanding of how a particular innovation type is identified and how the innovation process may be unique for that specific innovation type. Based on an empirical study covering 184 manufacturing firms in Turkey, Gunday, Ulusoy, Kilic, & Alpkan (2011) explore the effects of the organizational, process, product and marketing innovations on the different aspects of firm performance, including innovative, production, market and financial performances. They reveal the positive effects of innovations on firm performance in manufacturing industries. Serrat (2017) identified important factors such as idea sharing and knowledge transfer that affect on the harnessing creativity and innovation in the workplace.

The concept of innovation and its development is rapidly expanding for each specialized business sector. For instance, Hipp & Grupp (2005) introduced a new typology for innovation with a view to obtaining a better understanding of innovation in knowledge-intensive business services not manufacturing industries. Rodríguez, Nieto, & Santamaría, (2018) developed an empirical analysis on technological and professional knowledge-intensive services based on a large sample of business services for the period 2004–2007. They concluded that variety in international collaboration is more critical for technological knowledge-intensive services, however proximity to international partners is more significant for professional knowledge-intensive services. Nieves & Quintana, (2018) emphasized on the important role of Human Resource Management (HRM) practices on innovation level of organization in the hotel industry.

Recently, Klewitz & Hansen (2014), studied the challenges of implementing sustainability-oriented innovations (SOIs) that is the integration of environmental and social aspects into products and organizational processes for small and medium sized enterprises (SMEs). As well, Altenburg, Bhasin, & Fischer (2012) studied the SOIs issue for Automobile industry by emphasizing on electromobility.

To make innovation sustainable within the organization, it is significant to establish a well-defined innovation measurement system. The Organization for Economic Co-operation and Development (OECD) measures innovation as an activity not as an output (Dewangan & Godse, 2014). Brown and Svenson, (1988) worked on Research and Development (R&D) productivity measurement and considered a process-based approach, measured inputs, processing system, outputs, receiving system and outcomes. They recognized some of the main reasons why R&D measurement systems fail or succeed.

Cooper and Kleinschmidt, (1995) in their work on success factors for NPDs summarized ten performance metrics in two underlying dimensions; program impact and program profitability. These performance factors considered as the Y-and X-axes of a performance map. This way, a company based on its performance can be placed in one of solid performers, high-impact technical winners, low-impact performers, and dogs categories.

Muller, Välikangas, & Merlyn, (2005) proposed four perspectives to measure innovation as resource, processes, capability and leadership. Adams, Bessant, & Phelps (2006) in their review paper on innovation management measurement revealed six main perspectives ie. inputs, knowledge management, innovation strategy, organization and culture, portfolio management, project management and commercialization. In 2013, Cruz-Cázares et al. have proposed to calculate the coefficient of technological innovation activities by the help of global Malmquist index. This way, inputs such as R&D capital stock and high-skill staff, and outputs such as the number of patents were considered. Recently, Frishammar, Richtnér, Brattström, Magnusson, & Björk (2018) proposed an innovation auditing framework by considering triple trends of openness, servitization and digitalization. They claim this framework can support innovation management processes in increasingly dynamic and competitive business environments. Saunila, (2017) provided a systematic literature review on quantitative innovation measurement approaches.

3. Innovation Measurement

It is appropriate to look at the definition of innovation before we start discussing about innovation measurement. According to the presented definition, innovation is the transformation of an idea to a product, services or novel and improved industrial and business processes which are marketable. Innovation encompasses three stages and they are as follows:

1- Creation of an idea
2- Idea development
3- Commercialization

That's exactly why the application of term "innovation process" is more suitable. According to the definition of OECD about innovative company which was published in 1999, companies which have utilized and implemented technologically improved and modern processes within the period of investigation are called innovative.
Meanwhile, since Research and Development (R&D) is the most important source for innovation, it is essential to have a review of definition of R&D. In the seventeenth edition of the key OECD document for the collection of R&D statistics which is better known as *Frascati Ma*nual and is published in 2015 "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge" (OECD, 2015).

(Romijn & Albaladejo, 2002) addressed the issue of measurement of innovation ability in small electrical and Software Company in south UK in 2000 using 6 criteria which are categorized into two internal and external groups. In 2005, Hipp and Grupp addressed the subject of innovation measurement in service sector. The interesting research of (Becheikh, Landry, & Amara, 2006) manifested the necessity of innovation process cognition.
In fact, what is of extraordinary importance is the performance of an organization regarding innovation process.
One thing that we should consider is the quality of real performance of an organization within this process. Has organization had a successful innovation process? Do R&D employees and people who have great impact and contribution on innovation process have sufficient productivity? Are there appropriate time intervals between creation of an idea and its execution to compete in global market? Finally, are we able to compete in global market with current organization innovation processes? These are questions which are raised in innovation measurement discussion and of course elucidate the importance of the subject.
At the end, as pointed out, without measurement, control is impossible and management without control is also impossible. Without management, competitive power is lost and the final result of this trend is elimination from market. Hence, in recent global market competition, innovation measurement gains further significance and this is the main purpose of this paper.

4. THIO Model

Simply speaking, technology is divided into four aspects which are schematically shown in Figure 1:

- **Techno-ware**: is the equipment and hardware.
- **Human-ware**: is dependent to the specialization of existing human resource across an organization.
- **Info-ware**: includes manuals information, documents, technical plan, essential operations, maintenance and producing of hardware facilities.
- **Orga-ware**: is dependent to organizational structure, productivity activities and organizational mechanism (Khalil-Timamy 2002).

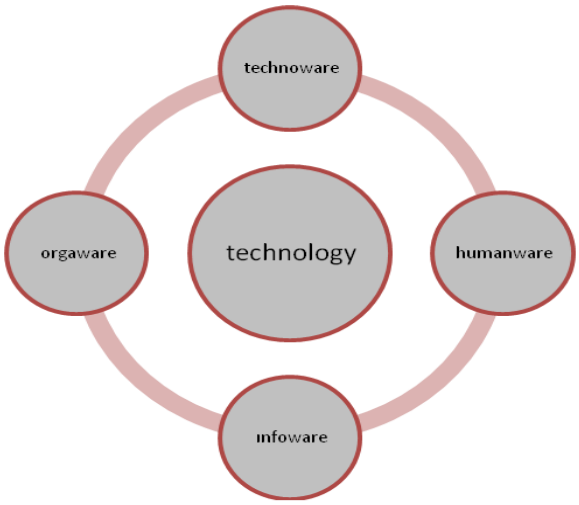

Fig.1. Schematic representation of technology

This classification of technology components was presented by the technology atlas team, in 1987. This indicates the necessity of multi-dimensional consideration of technology. This model tries to deliver an exhaustive and suitable orientation to cover entire aspects of technology. Hence, this model can be a basic suitable model for innovation measurement.

5. THIO Definition in Innovation Measurement

Our purpose is to measure Innovation. To this end, we intend to present a simple model which comprises appropriate criteria based on THIO classification.
According to presented definition, physical symbols (features) of technology such as machineries, chips and software packages are called Techno-ware. We attempt to specify four criteria in the field of Techno-ware and measure the company innovation condition regarding essential tools and physical equipment.
Human-ware indicates individual specialization, to this end; we have compiled four criteria regarding individual specializations measurement in line with innovation.
Info-ware indicates the knowledge related to physical symbols of technology and we have taken four criteria regarding knowledge exchange and enrichment into

consideration. Finally, Orga-ware reveals the organizational skills related to technology. Defined criteria for innovation measurement in this aspect are in line with innovation general cultures and skills throughout an organization. It deserved to notice that organizational process and procedures are included in this field.

6. THIO Based Innovation Measurement Model

The generality of model was explained in previous section. We look at innovation measurement from four different aspects, organization abilities are computed with respect to each four T, H, I, O aspects using defined criteria in each aspect.
These criteria have been collected among current available innovation measurement criteria which embrace sufficient exhaustivity. We will discuss how to measure innovation in next section.

6.1. T aspect measurement criteria (Techno-ware)

There are four criteria for this aspect:

6.1.1. What is the level of an organization regarding technology?

Technological position of an Organization is important in innovation measurement. The innovation value of a high-tech organization is not equivalent to a low-tech organization innovation value. Considering this distinction is therefore unavoidable.

6.1.2. What is the level of organization regarding equipment and tools required for innovation process?

Innovation process requires specific tools and equipment. IT infrastructure might be the most important factor.
Accessibility to reputable global resources and state-of-the-art technology are influential factors on these criteria. The more the organization is enjoying of progressive equipment and facilities, the more innovative power it will have.

6.1.3. R&D annual budget

However we can't assert that increase in budget will guarantee the improvement in innovation process, this is a very contributing factor that achievement of successful innovation is approximately unimaginable in absence of this factor.

6.1.4. Existence of specific and independent department to manage innovation process

This criterion is quite clear and reveals that how much important is innovation process for an organization. In fact, organizations, which have not established independent R&D department, are not eligible to be called organizations with sufficient infrastructure of innovation process.

6.2. H aspect measurement criteria (Human-ware)

We have given brief explanation about determined criteria in this aspect.

6.2.1. Number of R&D employees.

This criterion like R&D budget does not vouch for success but this is a criterion to determine the volume of activities towards innovation. Of course, it is worthwhile to mention that productivity in this criterion is a determinant factor (however, Measurement of R&D employment productivity defies another complete paper).

6.2.2. The number of registered annual papers in reputable scientific journals.

This criterion gauges the update of an organization; giving special attention to this criterion can possibly bring favorable results for any organization. Since, in global competition, global knowledge is highly essential. Therefore, we seek to highlight the importance of the same point in this criterion.

6.2.3. The average line of literacy among R&D employees.

On the one hand, Innovation is equal to change and it is always accompanied by resistance. On the other hand, innovation embraces all parts of an organization. Hence, the higher the average line of literacy among organization employees, the easier the reception of innovation process will be. Innovation process is accomplished more quickly and conveniently by employees holding higher degree of educations. Note that in nowadays global competition, time is a critical factor to assimilate and accommodate the change.

6.2.4. The average amount of R&D employee's salary.

This factor is a motivational factor. Equal sufficient salary along with mental tranquility is an essential factor for R&D employees. They exactly realize that they are working in an ideal environment with the best facilities. So, they expend their all-out efforts to achieve organizationally desirable goals.

6.3. I aspect measurement criteria (Info-ware)

This aspect, as was previously remarked; denotes the organizational knowledge and information. We have considered four criteria in this aspect and they are as follows:

6.3.1. The number of registered annual patent.

One of the most important outputs of R&D is patents. Number of patents is a determinant factor for innovation measurement. This criterion is the oldest factor to measure innovation.

6.3.2. The extent of growth in patents.

The most important point that we must bear in mind about patents is their movement trends. If the number of an organization registered patents follows an appropriate growth, one can visualize a good vision for organization.

6.3.3. The scope of cooperation with universities, scientific- research center and scientific journals.

Handling joint research projects with scientific centers, universities and collaboration with scientific journals, is a criterion by which an organization overall knowledge is assayed and appraised in different managerial and divisional levels.

6.3.4. The range of activities in relation to communication with customers to materialize their intangible (imperceptible) needs.

We know that nowadays (R&D fourth generation) resources for creation of an idea to develop a new product or process in addition to available knowledge (either R&D global knowledge) are the customers of an organization. Ultimately, customers are who to choose organization products.
Hence, victory golden key in competitive market is to identify and realize the hidden needs of customers.

6.4. O aspect measurement criteria (Orga-ware)

We have compiled four criteria to measure the organization capabilities and power, they are as follows:

6.4.1. The number of radical innovations.

Number of performed radical innovations is a very remarkable factor to measure organizational innovation power. The type of this innovation is very considerable because the impacts of radical innovations on organization are totally different from the way that incremental innovation influences the organization.

6.4.2. Then number of incremental innovation.

As was mentioned is previous criterion. This factor is a good indicator to measure organizational innovation power.

6.4.3. Handling joint projects with other corporations

Handling joint projects with other corporations is a positive and reinforcing factor because every single organization has its own special capabilities. Hence, execution of joint projects with others generates further synergy and consequently, further success

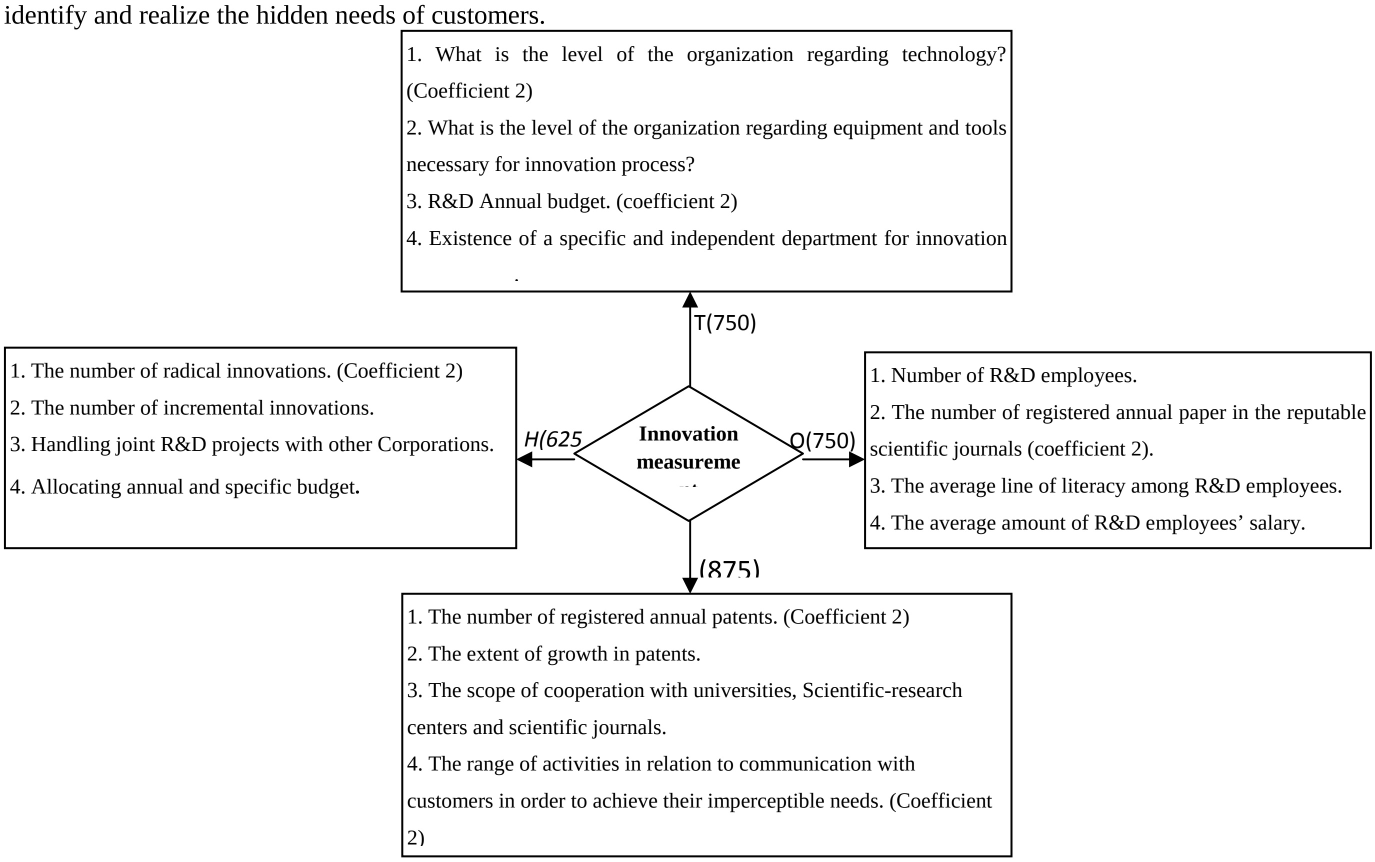

Fig. 2. The conclusive model for innovation measurement (each criterion 125 scores, total sum is 3000 scores).

6.4.4. Allocating annual and specific budget as a percentage of income or other factors to implement innovative-research projects.

This point, exactly the same as existence of innovation independent department, demonstrates the degree of organizational perception of innovation process significance. In this paper we have considered annual budget and existence of innovation independent department as necessary equipment. But having a ratified budget plan that mandates the organization to execute the budget plan properly is included in organizational plan and consequently in innovation organizational infrastructure.

7. Conclusive Model

In figure 2**,** the conclusive model which is in fact the conclusion of what was explained in the previous sections is shown. Explanations on the scoring method are provided in the next section

8. Method of Measurement

In this section the method of measurement of these criteria and type of scoring them will be discussed. The model acts in a way that each criteria bears 125 scores and the criteria has been divided into two categories: bearing coefficient 1 and coefficient 2. The score of each criterion, considering the relevant coefficient, will be added to the score of other criteria and finally will create the final score of its aspect. Based on this procedure (shown on the Figure 2), the attained scores together with the final score have been calculated out of 3000. What we have been talking about in this section is scoring the compiled criteria in all aspects. You should be notified that scoring most of the criteria depends on their average amount in the relevant industry (sector). This is inevitable as a result of distinction existed in different industrial sectors.

8.1. Techno-ware

8.1.1. What is the level of the organization regarding technology (High Tech, Low Tech, Normal) that we can allot the scores of 125, 25, and 75 to the organization. This criterion bears the coefficient 2.

8.1.2. What is the level of the organization regarding equipments and tools necessary for innovation process? (High level (125), Good (100), average (75), low level (50)). This scale bears the coefficient 1.

8.1.3. R&D Annual budget. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 2.

8.1.4. Existence of a specific and independent department for management. (It exists independently and perfectly (125), it exists but not fully independent (75), it is under construction (25), it does not exist (0)). This criterion bears the coefficient 1.

8.2. Human-ware

8.2.1. Number of R&D employees. (Score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 1.

8.2.2. The number of registered annual papers in reputable scientific journals. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 2.

8.2.3. The average line of literacy among the R&D employees. (PhD (125), M Sc (100), BS (75), AA (50), Diploma (25), below Diploma (0)). This criterion bears the coefficient 1.

8.2.4. The average amount of R&D employee’s salary. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 1.

8.3. Info-ware

8.3.1. The number of registered annual patents. (Score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 2.

8.3.2. The extent of growth in patents. (score of 125 if it is higher that 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 2.

8.3.3. The scope of cooperation with universities, Scientific-research centers and scientific journals. (Very high (125), high (100), Average (75), Low (50),Very Low (25), not at all (0)). This scale bears the coefficient 1.

8.3.4. The range of activities in relation to communication with customers in order to achieve their imperceptible needs. (Very high (125), high (100), Average (75), Low (50),Very Low (25), not at all (0)). This criterion bears the coefficient 2.

8.4. Orga-ware

8.4.1. The number of radical innovations. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 2.

8.4.2. The number of incremental innovations. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient 1.

8.4.3. Handling joint R&D projects with other Corporations. (score of 125 if it is higher than 1.5 times of the relevant industry (sector) average, Score of 25 if it is less than half of the industry average, and 75 if other cases). This criterion bears the coefficient 1.

8.4.4. Allocating annual and specific budget as a percentage of income or other factors to implement innovative and research projects. (Score of 125 if it is higher than 1.5 times of the relevant industry (sector) average (what percentage of the organization income), Score of 25 if it is lower than half of the industry average, and 75 if other cases). This criterion bears the coefficient (1) .

Table 1
The result of case study in Iran Khodro and Saipa

Row	Questions	Scores	
		Saipa	Iran Khodro
T-1	What is the level of the organization regarding technology?	75	75
T-2	What is the level of the organization regarding equipment and tools necessary for innovation process?	75	75
T-3	R&D annual budget	125	75
T-4	Existence of a specific and independent department for innovation management	125	75
H-1	The number of radical innovations	125	125
H-2	The number of incremental innovations	75	75
H-3	Handling joint R&D projects with other Corporations	75	75
H-4	Allocating annual and specific budget	75	125
I-1	The number of registered annual patents	25	25
I-2	The extent of growth in patents	25	25
I-3	The scope of cooperation with universities, Scientific-research centers and scientific journals	50	50
I-4	The range of activities in relation to communication with customers in order to achieve their imperceptible needs	50	50
O-1	Number of R&D employees	75	75
O-2	The number of registered annual papers in the reputable scientific journals	125	125
O-3	The average line of literacy among R&D employees	25	25
O-4	The average amount of R&D employees' salary	75	75
	Total Score	**1200**	**1150**

To appropriately appraise the result of model, the scores of these two companies have been analyzed and depicted by Radar chart (Figure 3).

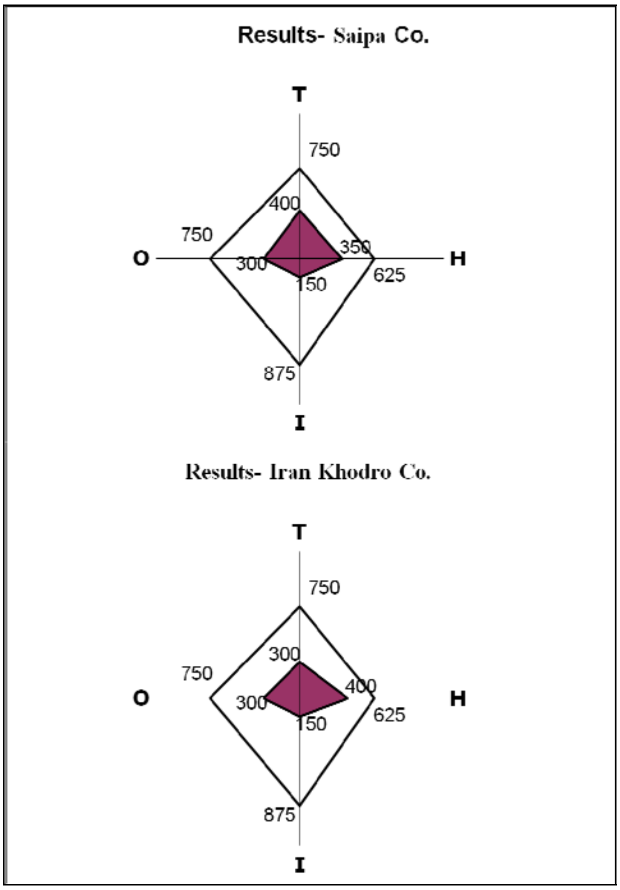

Fig.3. Radar charts of the results

As can be seen in figure 3 both of the companies are not located in good position regarding Info-ware aspect performance. Iran-khodro automotive company needs to balance its innovation process by focusing more on Info-ware, Orga-ware and Techno-ware aspects. However, Saipa should concentrate on Info-ware, Orga-ware and Human-ware.

9. Conclusion

According to the importance of the innovation measurement and existence of many different criteria in this field, we should be able to measure innovation using a suitable, simple but comprehensive model. In this paper we have benefited from THIO classification model and prepared our model by gathering four criteria for each aspect (Figure 2). Each criterion has got 125 scores and the weighted coefficient of 1 or 2. The weighted sum of the scores of the criteria will construct the conclusive score of each aspect and finally shaping the whole model that will be calculated out of 3000.

The organization computing its own score and drawing its relevant score in this model, would be able to figure out its strengths and weaknesses.

According to Figure 3, we have been successful in achieving a simple (and exhaustive to the possible extent) model enabling us to measure the innovation. Certainly, this model is not out of any errors, but the path is open for any future research to make the model more comprehensive in a way that it completes the criteria, makes the proposed model more effective, and perform a case study in all companies of specific sector.

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