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INNOVATION REALIZATION WITH THE SUPPORT OF TQM PRACTICES: A PERSPECTIVE FROM IRAN'S TIRE INDUSTRY

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ABSTRACT

Total quality management is a management approach for the continuous improvement of products and services with the participation of all employees and the organization. Innovation refers to the commitment to create new and improved versions of existing products, services, operations, and other items. TQM and innovation predict the survival determinants of micro, small and medium enterprises, so TQM practices support the realization of innovation. The main objective of this research is to investigate the impact of TQM practices on the realization of innovation. For this purpose, by examining quality system management and innovation from a process point of view while identifying 13 tools of TQM and five factors of innovation, the relationship between these two has been investigated. FAHP and DEA techniques are used to develop this model. The results indicate that TQM components develop organizational innovation. As a result, the TQM environment could be an appropriate platform to flourish innovation in an organization.

1. INTRODUCTION

With the competition of companies to emerge successful in a business field having gone closed in the present business world, innovation of production and also of product and services presentation could be one of the tools for companies to seek supremacy and success in today's closed competition (Hossain & Hossain, 2019)). Promising to achieve ultimate business results, today, Total Quality Management (TQM) is faced with a top position in the developed world as well as an eye-catching acceptance (Zhou et al., 2018).

TQM is not a barrier in the way of innovation. The dimensions of TQM, such as customer focus, education, empowerment, teamwork, the logic of manufacturing process analysis, and benchmarking, could help an organization be more innovative in its activities (Dubey and Singh, 2015). To arrive at such a destination; nevertheless, TQM concepts must be better apprehended by management, especially senior management.

Supporting manufacturing quality and effectiveness, TQM is still known as the primary element in developing competitive advantage for organizations (Lam et al., 2012; Bhatia and Awasthi, 2018). There is a worry; however, that quality improvement does not support some organizations' innovation capabilities. Since innovation requires a change in an organization's operating systems, it has to be done in a top-bottom fashion. As a result, it faces problems that need primary advancing changes to resolve. Through the execution of

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TQM by all the organization members, from the shop floor to the office departments, many of the required changes are provided (Honarpour et al., 2018). TQM is a subject related to change and must match modern work conditions, competition, and the environmental conditions moving toward what is caused by business innovation (Anvari et al., 2011).

Critical success factors (CSFs) are also considered for realizing the competitive advantage. It is often not clear to companies what factors have a more effective role. Hence, the performance of the companies in the competition could not be evaluated appropriately and ranked without simultaneous consideration of the CSFs (Molina-Azorín et al., 2015).

Thereupon, to evaluate a company's performance, application of the Multiple Criteria Decision Making (MCDM) methods, founded based on the multi-attribute utility theory, are common for the presentation of better performance analysis. Considering the importance of Iran's Tire industry in recent years, the multi-attribute decision-making model is necessary for the Tire manufacturing companies to rank CSFs and TQM on the basis that can guarantee a competitive advantage for the company.

Reviewing the literature based on a platform of TQM, this research firstly extracts the CSFs for innovation. These CSFs are given to the senior managers and experts. They evaluate these factors using pairwise comparison; weights of factors are obtained. Subsequently, factors are evaluated by quality experts as well as other personnel, and each factor's average score is elicited. The steps of the study are done through Data Envelopment Analysis (DEA) to decide the best alternative among other alternatives based on the existing criteria.

This study aims to identify the common factors of TQM and innovation and proposes a TQM and innovation interaction model. Secondary goals include:

1) Identification of the requirements for innovation realization
2) Identification of tools and techniques of TQM to the competitive advantage
3) Maximizing innovation within the context of TQM

2. LITERATURE REVIEW

2.1 TQM and Innovation

According to Leavengood et al. (2014), TQM is one of the top international approaches recognized for achieving a high level of quality and, as a result, leads to better organizational performance (Cruz et al., 2014). In a country like Iran, TQM has positively affected innovation performance in manufacturing and service-providing companies (Jackson et al., 2016). TQM also positively affects customer satisfaction (Fernandes & Fernandez, 2022). The findings of Abrunhosa and Sá (2008) indicate that executing TQM principles promises innovation. Therefore, TQM with continuous improvement and innovation is a solution leading to customer satisfaction (Li et al., 2018).

The need for business innovation is one of the main reasons companies accept TQM. Companies employ innovation in two primary ways: either through copying innovation or the development of their innovations. The first strategy could be helpful in solutions in which companies possess competitive advantages, like the following conditions: low wages, easy access to raw materials, exclusive markets, and multiple product supplies. Meanwhile, the second strategy is better to obtain a competitive advantage. This is useful not only for processes and product innovation but also for management innovation (Pekovic and Galia, 2009). TQM approach may be helpful to both strategies. Companies using a TQM approach can more readily accept their employees' satisfaction in entrance and acceptance of a new idea in the form of continuous improvement habits presented by TQM (Tarí et al., 2018).

One of the most important TQM factors is the need for an appropriate customer focus. Companies must identify the present and future demands and customer satisfaction and loyalty levels. Predictably, the demand for global consumers in less developed countries will increase daily. Whatever the change is, the complete customer needs must be considered. Hence, TQM motivates process innovation (Perdomo-Ortiz et al., 2006). Another aspect of TQM is associated with the importance of education programs. Having access to well-educated clerks facilitates business innovation.

Furthermore, in a TQM environment, employees accept functional methods more rapidly. This does not merely matter in association with employees' education and training. Instead, it is also vital for the development of knowledge as well as the abilities of the individual. A well knowledgeable clerk usually performs better in apprehension and acceptance of new performance systems. This is more secure about future jobs with more intellectual aspects and less mechanical inherence (Honarpour et al., 2018).

TQM approach in process stream management is legal in terms of logic. Statistical process control and other quality management practices and technique approaches pave the way for a logical analysis of the problem and decision-making through real data. Hence, a company that takes into account the TQM philosophy is more demanding of acceptance of and compatibility with innovation (McAdam and Armstrong, 2001). Hung et al. (2011) validated the positive impact of TQM on innovation performance in the high-tech industry. Ooi et al. (2012), in a study, demonstrated that TQM supports innovation performance in the manufacturing industry.

Moreno-Luzon et al. (2013) studied the role of TQM and innovation on cultural change. They authorized cultural change created by combining TQM and innovation. Bon et al. (2012) and Bon and Mustafa. (2013), in a reviewing study, approved the impact of TQM on innovation in service organizations. Aminbeidokhti et al.'s (2016) study shows the mediated TQM effect on organizational innovation in higher education. Augusto et al. (2014) revealed that innovation and organizational performance are in the framework of a TQM philosophy. Raja and Wei (2014) examined the relationship between innovation and Quality Practices; and their effect on firm performance. Shuaib et al. (2021) showed the quality management effects on innovation. Sila (2022) highlighted that TQM practices affect changed types of innovations differently. In addition, Akanmu et al. (2020) explained the regulations of excellence models when implementing TQM practices involving innovation and customer focus.

The benchmarking aspect is innovative; since the aim of this aspect is to know if other organizations do better or not so that they could be used in the development of methods to transfer process improvements and achieve organizational efficiency through the introduction of top examples, copying, and matching them (Prajogo, 2006; López-Mielgo et al., 2009). Innovation needs a change in the organization's operating systems (Lebedeva et al., 2019). Consequently, it must be done in a top-bottom fashion by all. Nonetheless, through a TQM policy by all the company members, from the shop floor to the office departments, many of the required changes are provided (Honarpour et al., 2018).

2.2 Maximization of innovation in a TQM environment

Innovation is the ability of a company to develop a new thing through creativity. TQM is a system for improvement of the competitive advantage in which the TQM practices support innovation realization. The atmosphere for innovation must be there for an organization to be successful. (Sila, 2022). For this reason, many researchers confirm the positive effect of TQM on innovation (Prajogo and Sohal, 2003 and 2004; Abrunhosa and Sá, 2008; López-Mielgo et al., 2009; Long et al., 2015; Aminbeidokhti et al., 2016; Zhang et al., 2016; Li et al., 2018; Antunes et al., 2021; Fernandes and Fernandez, 2022). Some even believe TQM as the pioneer of and caller for innovation (McAdam and Armstrong, 2001; Prajogo, 2006; Perdomo-Ortiz et al., 2006; Pecovic and Galia, 2009; Yusr, 2016 ; Honarpour et al., 2018; Tarí and García-Fernández, 2018; Zhou et al., 2018; Lebedeva et al., 2019; Khalfallah et al., 2021; Shuaib et al. 2021; Masrom et al., 2022; Sila, 2022). Simultaneous use of innovation and quality leads to performance raise. It is through the application of both (quality and innovation) enabling a company presents new things to the market, a product of high quality and low cost.

2.3 Compatibility of TQM and innovation criteria

TQM, as one of the most common management philosophies, is part of the most vital strategies to improve the position of an organization in the market (Akanmu et al., 2020). In order to better understand the positive effects of TQM on innovation performance, it should be integrated with technology management (Sila, 2022). Raphael (2010) presented a list of TQM practices that may be used to improve the level of creative skills. The list includes 5W2H (What, who, why, when, where, how, how much/many), mind maps, lateral thinking, Kano Model, voice of the customer, benchmarking, seven quality control (QC) tools, seven management and planning tools, quality function deployment, SWOT (Strengths, Weaknesses, Opportunity, Threats) analysis, theory of constraints, TRIZ (an abbreviation of a Russian multi-word expression meaning inventive problem solving), value stream mapping. The mentioned list is considered in this research work.

A summary of the TQM practices definitions are given in Table 1 (Bon and Mustafa., 2013; Augusto et al., 2014; Raja and Wei., 2014; Aminbeidokhti et al., 2016; Yusr, 2016; Tarí and García-Fernández, 2018, Antunes et al., 2021; Fernandes and Fernandez, 2022). Raphael (2010) summarizes the innovation criteria in 10 items in a study. Out of 26 resources used, ten criteria were selected (with a total frequency of 80) from innovations of different frequencies (3-20); three criteria with 58% of observations (a frequency of 46), and 7 (70%) criteria with 42% of observations (a frequency of 34). The three criteria (product design, process management, innovation orientation) with high frequency (46 out of 80) are selected as the primary criteria for innovation maximization.

On the other hand, there are two critical factors in innovation realization: innovation conformity time and implementation costs. The innovation conformity time is an innovative reflector of a company in which low cost is a competitive advantage and innovation is a high priority (Abrunhosa and Sá, 2008). Hence, if the innovation conformity time and the cost competitive reaction are economic, the technology innovation completes, and organizational innovation is supported.

Table 1. TQM effective tools for the maximization of innovation

TQM tools	Definition
5W2H	In relation to the product or process, seven questions will be asked. Questions start with what, who, when, where, why, how, and how many/how much.
Intellectual maps	A plan that shows the relationships between beliefs. It is utilized in taking notes, brainstorming, and problem-solving.
Lateral thinking	Lateral thinking is a tool for problem-solving and brainstorming to help things out of range.
Kano model	This system is designed for prioritizing of developing ideas of what customer wants.
Voice of customer	Receiving customer's voice through an interview, customer survey, centralized groups, defined or undefined customer needs in a field customer has expressed.
Making pattern	In patterning best methods in three contexts: processes, data, and strategy, have been identified.
Seven old tools of QC	Includes: flow forms, a control table, column form, cause and effect form, Pareto form, distribution form, and control form.
Seven new tools of management and planning	Includes dependency form, communication form, tree form, matrix form, matrix analysis of data, vector form, and decision process planning.
Development of quality performance	This technique receives the customer's voice and, after prioritizing, increases satisfaction and loyalty.
SWOT analysis	A tool for determining business strategies through identifying strengths, weaknesses, opportunities, and threats.
Theory of constraints	The philosophy of management and improvement; states that if the product is going to be improved, the limitations and bottlenecks should be identified and improved.
TRIZical Creanovatology	It is the Russian acronym for the "theory of the resolution of invention-related tasks." This is a method for solving problems that do not have known solutions.
Value stream mapping	VSM gives a view of the required steps in a process.

As a result, based on what was mentioned earlier, there are two groups of innovation: first, product design, process management, and innovation orientation; and second: the conformity time and the cost of implementation. A concise definition for each innovation criterion (Ooi et al., 2012; Moreno-Luzon et al., 2013; Augusto et al., 2014; Golmohammadi et al., 2014; Miranda Silva et al., 2014; Zeng et al., 2015; Honarpour et al., 2018; Zhou et al., 2018; Lebedeva et al., 2019; Khalfallah et al., 2021; Kulenović et al., 2022 Masrom et al., 2022) is given in Table 2.

Table 2. The rating scale for the violence parameter

Innovative indicators	Definition
Adaptation time	Adaptation time for some required production is the realization of optimal adaptation changes in the system based on the required operations.
Running cost	There is always a need for the cost to design and produce a new product.
Product design	Product design is the process of creating a new product. It may include: quality, performance, reliability, providing new services, et cetera, for innovation.
Process management	Process management focuses on what is needed through brainstorming and then producing a new product as an innovation.
Tendency to innovation	Creates a tendency to innovation as a culture since culture creates worthwhile new strategies.

The inherence of criteria group 1 is that the higher, the better (High-quality product design, high-quality management process, high orientation toward innovation). On the contrary, the inherence of criteria group 2 is that the lower, the better (less time for innovation conformity and less cost to implement it). On the other hand, there are two dimensions, input, and output, in DEA. Everything with the "the more, the better" inherence is called an output; everything with "the less, the better" inherence is called input (Anvari et al., 2014). Hence, the innovation criteria could be registered to DEA. This means that product design, process management, and innovation orientation could be considered as output and time and cost as input.

3. METHODOLOGY

Generally speaking, from the purpose point of view, this research is an applied one. From the method point of view, it is included in descriptive research. For data collection in the literature review, library research is applied; for data collection and determination of the weights of criteria, a survey is conducted with the participation of the experts. Speaking of this aspect, field research using the questionnaire is applied. On the other hand, given that this research is based on analyses made by experts, the population and sample include the QC experts in Iran's Tire industry. The conceptual model is shown in Figure 1.

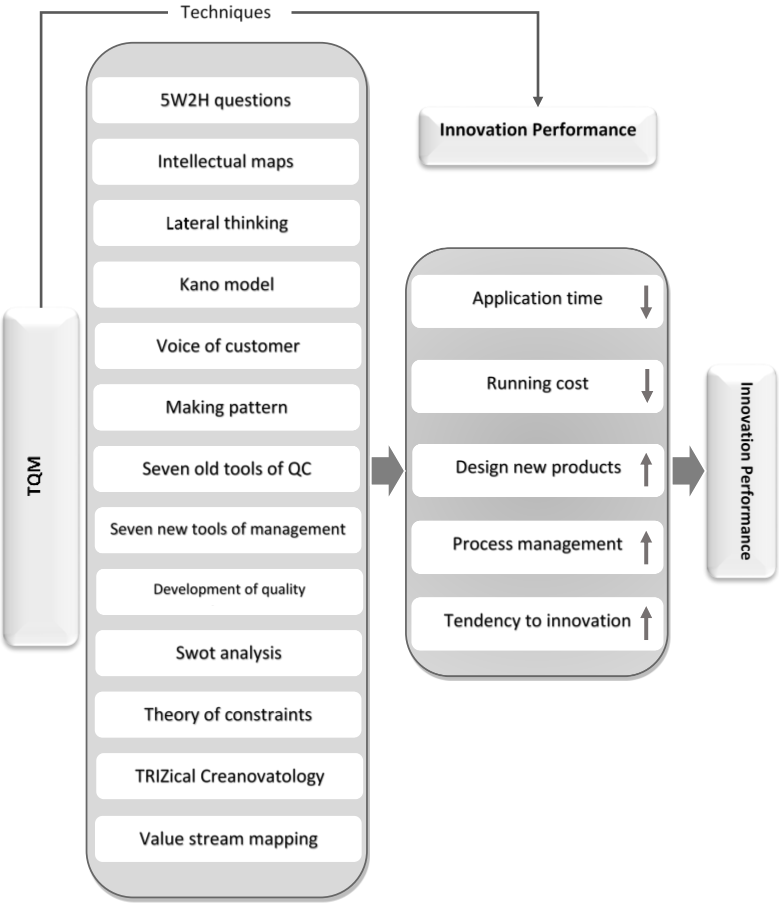

Figure 1. Conceptual model

3.1. Data analysis

The primary purpose of this research is to explore the factors and techniques for successful TQM, innovation criteria, the role of TQM on innovation performance, and the ranking of TQM techniques through applying the fuzzy hierarchical method and DEA. Data from the experts is also collected, along with acquiring and investigating the previous research resources. Therefore, questionnaires are distributed among experts. The first questionnaire is for the pairwise comparison of the criteria, and the second questionnaire is for comparing the alternatives based on the criteria, which were filled out by five quality experts of tire manufacturing companies. Subsequently, the Analytic Hierarchy Process (AHP), Fuzzy AHP (FAHP), and DEA methods are applied to analyze the data. The research's hierarchical structure and operation process are designed in Figures 2 and 3.

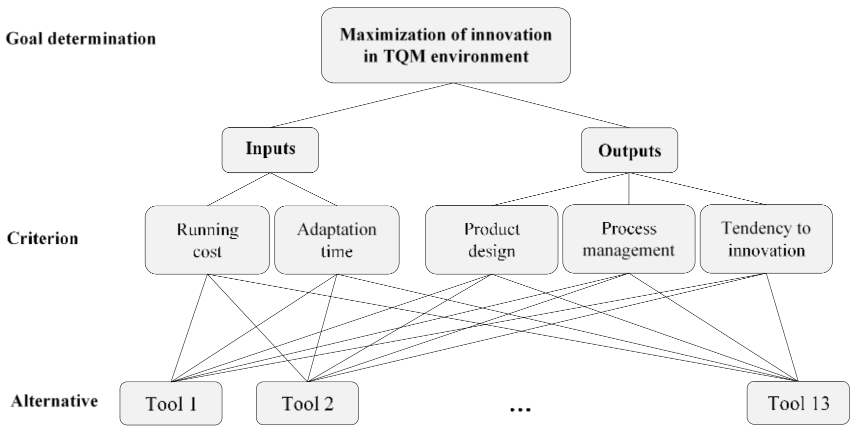

Figure 2. Hierarchical structure

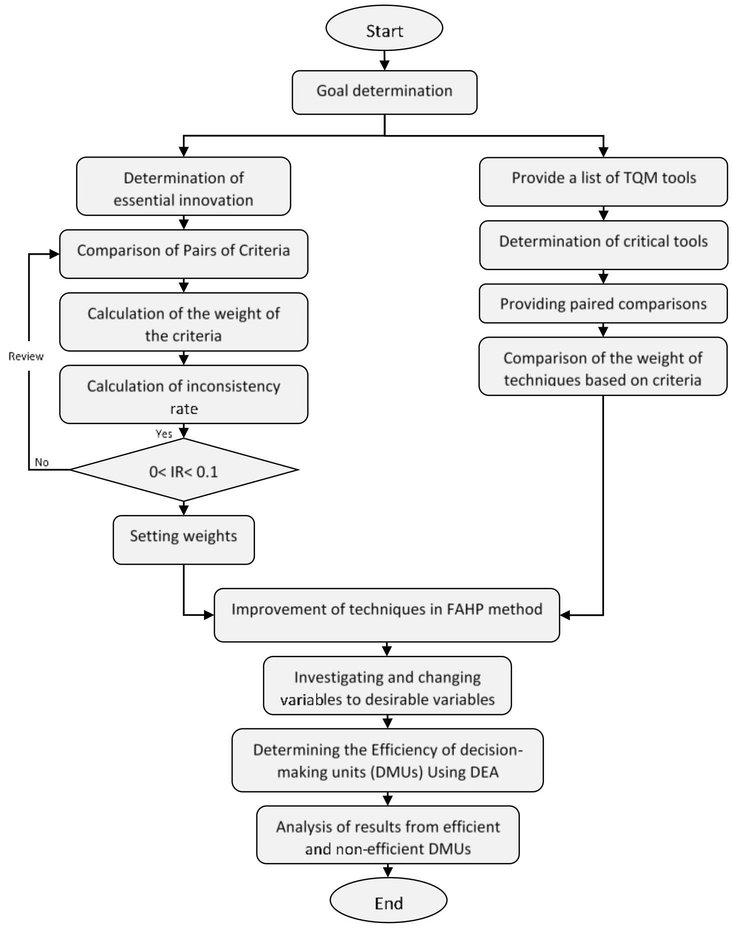

Figure 3. the operation process of DEA

3.1.1. Inconsistency rate determination

The following stages (Saaty and Özdemir, 2014) are carried out to determine the inconsistency rate:

- The criteria pairwise comparison
- Obtaining the geometric mean
- Summation of each column
- Normalization
- Obtaining the row mean
- Determination of the weighted summation vector
- Determination of the consistency vector
- Calculation of the inconsistency rate

3.1.2. Calculation of the criteria weights through FAHP

With the use of a rating matrix obtained from the ideas of the five experts, the following steps (Anvari et al., 2013) are to be taken:

Step 1 - Formation of the data table
Consider the following two triangular fuzzy numbers drawn in Figure 4:

$$M_1 = (l_1, m_1, u_1) \text{ and } M_2 = (l_2, m_2, u_2)$$

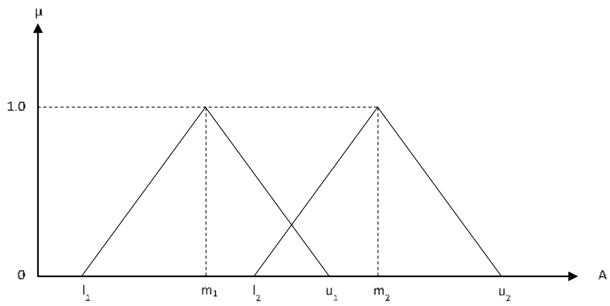

Figure 4. Triangular fuzzy numbers

Its mathematical operators are defined as follows:

$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$
$M_1 \times M_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$
$M_1^{-1} = (1/u_1, 1/m_1, 1/l_1); M_2^{-1} = (1/u_2, 1/m_2, 1/l_2)$

To form the data table, the greatest, the lowest, and the average (of the five experts' scores) are considered as the three triangular numbers (Table 3).

Table 3. Data based on triangular fuzzy model

	Adaptation time	**Running cost**	**Product design**	**Process management**	**Tendency to innovation**
Adaptation time	(1, 1, 1)	(0.25, 0.33, 0.5)	(0.33, 0.5, 1)	(1, 1.2, 2)	(0.33, 0.45, 0.5)
Running cost	(2, 3, 4)	(1, 1, 1)	(2, 3, 4)	(4,4.4,5)	(4, 5.2, 6)
Product design	(1, 2, 3)	(0.25, 0.33, 0.5)	(1, 1, 1)	(2, 3.2, 4)	(1, 1.6 ,2)
Process management	(0.5, 0.83, 1)	(0.2,0.23 ,0.25)	(0.25,0.31, 0.5)	(1, 1, 1)	(0.33, 0.38, 0.5)
Tendency to innovation	(2, 2.2, 3)	(0.17, 0.19,0.25)	(0.5,0.63,1)	(2, 2.6, 3)	(1, 1, 1)

Step 2 - Determination of the vector S_i
In the extent analysis method, for each row of the pairwise comparison matrix, the S_k, which is itself a triangular number, is calculated as follows (1):

$$S_k = \sum_{j=1}^{n} M_{k1} \times \left(\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij}\right)^{-1} \quad (1)$$

K: Number of rows
I: Alternatives
J: Criteria

Hence, the summation of the fuzzy numbers of each row is obtained by the formula (2):

$$\sum_{j=1}^{n} M_{k1} \quad (2)$$

1+0.25+0.33+1+0.33= 2.91 1+0.33+0.5+1.2+0.45= 3.48 1+0.5+1+2+0.5= 5	**Vector 1 - Summation of the fuzzy numbers of row 1**
2+1+2+4+4= 14 3+1+3+4.4+5.2=16.6 4+1+4+5+6= 20	**Vector 2 - Summation of the fuzzy numbers of row 2**
1+0.25+1+2+1=5.25 2+0.33+1+3.2+1.6=8.13 3+0.5+1+4+2=10.5	**Vector 3 - Summation of the fuzzy numbers of row 3**
0.5+0.2+0.25+1+0.33=1.28 0.83+0.23+0.31+1+0.38=2.75 1+0.25+0.5+1+0.5=3.25	**Vector 4 - Summation of the fuzzy numbers of row 4**
2+0.17+0.5+2+1=5.67 2.2+0.19+0.63+2.6+1=6.62 3+0.25+1+3+1=8.25	**Vector 5 - Summation of the fuzzy numbers of row 5**

The summation of fuzzy numbers of each level (the smallest, the average, and the greatest) is calculated by the formula (3):

$$\left(\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij}\right) \quad (3)$$

(1+0.25+0.33+1+0.33) + (2+1+2+4+4) + (1+0.25+1+2+1) + (0.5+0.2+0.25+1+0.33) + (2+0.17+0.5+2+1) = 29.11	Summation of the smallest fuzzy numbers
(1+0.33+0.5+1.2+0.45) + (3+1+3+4.4+5.2) + (2+0.33+1+3.2+1.6) + (0.83+0.23+0.31+1+0.38) + (2.2+0.19+0.63+2.6+1) = 37.58	Summation of the average fuzzy numbers
(1+0.5+1+2+0.5) + (4+1+4+5+6) + (3+0.5+1+4+2) + (1+0.25+0.5+1+0.5) + (3+0.25+1+3+1) = 47	Summation of the largest fuzzy numbers

Then, concerning formula (4), and eventually, according to formula (5), the following calculations for S1-S5 are made:

$$\left(\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij}\right)^{-1} \quad (4)$$

$$S_k = \sum_{j=1}^{n} M_{k1} \times \left(\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij}\right)^{-1} \quad (5)$$

S1= (2.91, 3.48, 5) X (1/47, 1/37.58, 1/29.11) = (0.0619, 0.0926, 0.1718)

S2= (14, 16.6, 20) X (1/47, 1/37.58, 1/29.11) = (0.2979, 0.4417, 0.687)

S3= (5.25, 8.13, 10.5) X (1/47, 1/37.58, 1/29.11) = (0.1117, 0.2163, 0.3607)

S4= (1.28, 2.75, 3.25) X (1/47, 1/37.58, 1/29.11) = (0.0272, 0.0732, 0.1116)

S5= (5.67, 6.62, 8.25) X (1/47, 1/37.58, 1/29.11) = (0.1206, 0.1762, 0.2834)

Step 3 - Order of magnitude

The orders of magnitude are now calculated for each element over other elements:

$V(M_1 \geq M_2) = 1; \text{if}, m_1 \geq m_2)$
$V(M_1 \geq M_2) = hgt(m_1 \cap m_2);\ \text{otherwise}$
$V(S_1 \geq S_2) = (u_1 - l_2)/((u_1 - l_2) + (m_2 - m_1)$

Calculation of the orders of magnitude for each element over other elements in the form of pairwise comparison:

S1>S2= (0.17-0.29))/ (0.17-0.29) + (0.44-0.09) =0.52
S1>S3= (0.17-0.11)/ (0.17-0.117) + (0.22-0.093) =0.83
S1>S4= 1
S1>S5= (0.17-0.12)/ (0.17-0.12) + (0.18-0.09) =0.38
S2>S1= 1
S2>S3= 1
S2>S4= 1
S2>S5= 1
S3>S1= 1
S3>S2= (0.36-0.29)/ (0.36-0.29) + (0.44-0.22) =0.22
S3>S4= 1
S3>S5= 1
S4>S1= (0.11-0.062)/ (0.11-0.06) + (0.09-0.07) = 0.96
S4>S2= (0.11-0.29)/ (0.11-0.29) + (0.44-0.07) =0.95
S4>S3= (0.1116-0.1117)/ (0.1116-0.1117) + (0.22-0.07) =0.1
S4>S5= (0.1116-0.12)/ (0.1116-0.12) + (0.22-0.18) = 0.2
S5>S1= 1
S5>S2= (0.1116-0.29)/ (0.1116-0.29) + (0.44-0.18) = 0.82
S5>S3= (0.28-0.11)/ (0.28-0.11) + (0.21-0.18) =0.81
S5>S4= 1

Given the results obtained in the last step, orders of magnitude are now calculated for each element over others in aggregate form:

$$V(M_1 \geq M_2, \dots, M_k) = \mathrm{Min}[V(M_1 \geq M_2) \dots, V(M_1 \geq M_k)]$$

V (S1≥ S2, S3, S4, S5) = Min (0.52, 0.83, 1, 0.38) = 0.38
V (S2≥ S1, S3, S4, S5) = Min (1, 1, 1, 1) = 1
V (S3≥ S1, S2, S4, S5) = Min (1, 0.22, 1, 1) = 0.22
V (S4≥ S1, S2, S3, S5) = Min (0.96, 0.95, 0.1, 0.2) = 0.1
V (S5≥S1, S2, S3, S4) = Min (1, 0.82, 0.81, 1) = 0.81

Step 4 - Normalization and calculation of weights
After that, summing up the results according to the formula (6):

$$W' = [W'(c_1), W'(c_2), \dots, W'(c_n)]^T \qquad (6)$$

$$W = 1 + 0.22 + 0.1 + 0.81 = 2.51$$

Afterward, the normalization needs to be done using the following formula (7):

$$W_i = \frac{W_i'}{\sum W_i'} \qquad (7)$$

W_i= (0.38/2.51); (1/2.51); (0.22/2.51); (0.1/2.51); (0.81/2.51)

Concisely, after the above calculations, the results will be the criteria weights on a fuzzy basis.

W_i= (0.15, 0.40, 0.09, 0.04, 0.32)

3.1.3. Data envelopment analysis for ranking

The hierarchical structure of the DEA approach is shown in Figure 2. The first level's purpose is specified (maximizing innovation in a TQM environment). In the second level, the criteria are determined, selecting two criteria (implementation cost and conformity time) as inputs and three criteria (product design, process management, and innovation orientation) as outputs. In the third row, there are 13 items from the TQM practices and techniques (Figure 2). This section explains the DEA method's application for ranking alternatives with several stages.

Stage 1 - Preparation of the scoring table by experts

Table 4 shows the scoring of the alternatives based on the five criteria by the five quality experts of Iran's Tire manufacturing companies.

Table 4. Grading 13 alternatives based on five criteria

alternatives	Adaptation time	Running cost	Product design	Process management	Tendency to innovation
5W2H	(1,2,1,2,3)	(3,4,3,2,7)	(5,5,5,3,7)	(3,3,3,2,3)	(3,2,3,2,3)
Intellectual maps	(3,2,3,2,3)	(4,5,4,4,3)	(5,4,8,5,3)	(5,4,5,2,3)	(1,1,2, 2,5)
Lateral thinking	(4,5,4,4,7)	(4,4,4,3,3)	(2,3,2,2,3)	(3,2,2,2,7)	(5,5,5,2,3)
Kano model	(5, 5,5,4,9)	(5,4,5,3,7)	(3,3,3,2,5)	(5,4,4,2,9)	(3,2,3,2,3)
Voice of customer	(3,3,2,2,5)	(5,5,5,2,3)	(5,5,5,4,3)	(3,2,4,3,3)	(1,1,2, 2,5)
Making pattern	(5,1,5,2,7)	(5,3,5,3,3)	(3,2,2,2,3)	(4,4,5,2,7)	(5,5,5,2,3)
Seven old tools of QC	(4,3,4,3,3)	(4,4,4,3,5)	(4,5,4,3,7)	(3,2,2,2,3)	(5,5,5,3,7)
Seven new tools of management and planning	(1,2,1,3,2)	(3,4,2,3,3)	(5,5,7,5,5)	(2,1,3,2,3)	(5,4,8,5,3)
Development of quality performance	(5, 5,7,4,3)	(5,3,5,5,5)	(2,2,2,2,5)	(5,5,6,3,3)	(2,3,2,2,3)
SWOT analysis	(5,5,5,4,5)	(5,3,6,2,5)	(3,4,2,2,1)	(5,5,5,2,3)	(5,5,5,4,3)
Theory of constraints	(2,4,1,3,3)	(3,4,3,3,3)	(5,4,5,2,5)	(3,2,3,2,3)	(3,2,2,2,3)
TRIZical Creanovatology	(2,3,2,2,5)	(3,5,2,2,3)	(4,5,4,3,2)	(1,1,2, 2,5)	(4,5,4,3,7)
Value stream mapping	(3,5,3,4,3)	(4,5,4,3,7)	(5,5,5,2,5)	(3,5,4,2,3)	(5,5,7,5,5)

Stage 2 - Calculation of the geometric mean
Here, each cell of Table 4 needs to be turned into one score through the geometric mean. The following is calculated to obtain cell one, as an example:

$$(1 \times 2 \times 1 \times 2 \times 3)^\wedge 1/5 = 1.64$$

Results obtained from the whole operation are demonstrated in Table 5.

Table 5. The geometric mean of the 13-sub-categorical matrix based on five criteria

alternatives	Adaptation time	Running cost	Product design	Process management	Tendency to innovation
5W2H	1.64	3.47	4.83	2.77	2.55
Intellectual maps	2.55	3.98	4.74	3.59	1.82
Lateral thinking	4.68	3.57	2.35	2.79	3.76
Kano model	5.38	4.62	3.06	4.28	2.55
Voice of customer	2.83	3.76	4.32	2.93	2.19
Making pattern	3.23	3.68	2.35	4.07	3.76
Seven old tools of QC	3.37	3.95	4.42	2.35	4.83
Seven new tools of management and planning	1.64	2.93	5.35	2.05	4.74
Development of quality performance	4.62	4.51	2.40	4.23	2.35
SWOT analysis	4.78	3.90	2.17	3.76	4.32
Theory of constraints	2.35	3.18	3.98	2.55	2.35
TRIZical Creanovatology	2.61	2.83	3.44	1.82	4.42
Value stream mapping	3.52	4.42	4.16	3.25	5.35

Stage 3 - Effect of weight on a decision matrix

In this stage, the matrix obtained from the geometric mean (Table 5) is multiplied by the fuzzy weighted matrix (obtained from step 4 of section 3.1.2) so that the weighted effect of criteria is seen in the ranking (Table 6).

The weighted matrix, obtained from a fuzzy method, is as follows:

$$W_i = (0.15, 0.40, 0.09, 0.04, 0.32)$$

Table 6. The geometric mean of the 13-sub-categorical matrix and the weight of five criteria

	0.15	**0.40**	**0.09**	**0.04**	**0.32**
alternatives	**Adaptation time**	**Running cost**	**Product design**	**Process management**	**Tendency to innovation**
5W2H	1.64	3.47	4.83	2.77	2.55
Intellectual maps	2.55	3.98	4.74	3.59	1.82
Lateral thinking	4.68	3.57	2.35	2.79	3.76
Kano model	5.38	4.62	3.06	4.28	2.55
Voice of customer	2.83	3.76	4.32	2.93	2.19
Making pattern	3.23	3.68	2.35	4.07	3.76
Seven old tools of QC	3.37	3.95	4.42	2.35	4.83
Seven new tools of management and planning	1.64	2.93	5.35	2.05	4.74
Development of quality performance	4.62	4.51	2.40	4.23	2.35
SWOT analysis	4.78	3.90	2.17	3.76	4.32
Theory of constraints	2.35	3.18	3.98	2.55	2.35
TRIZical Creanovatology	2.61	2.83	3.44	1.82	4.42
Value stream mapping	3.52	4.42	4.16	3.25	5.35

Table 6 indicates that the first row is the fuzzy weighted matrix, and the rest is the same as Table 5. The multiplication result is shown in Table 7. For instance, element A11 (0.15) in Table 7 is obtained as follows:

$$1.64 \times 0.15 = 0.25$$

Table 7. Grading of the 13-sub-categorical matrix after applying the weight

alternatives		Adaptation time	Running cost	Product design	Process management	Tendency to innovation
5W2H	A1	0.25	1.39	0.43	0.11	0.82
Intellectual maps	A2	0.38	1.60	0.43	0.14	0.58
Lateral thinking	A3	0.70	1.43	0.21	0.11	1.20
Kano model	A4	0.81	1.85	0.28	0.17	0.82
Voice of customer	A5	0.42	1.50	0.39	0.12	0.70
Making pattern	A6	0.48	1.47	0.21	0.16	1.20
Seven old tools of QC	A7	0.51	1.58	0.40	0.09	1.55
Seven new tools of management and planning	A8	0.25	1.17	0.48	0.08	1.52
Development of quality performance	A9	0.69	1.80	0.22	0.17	0.75
SWOT analysis	A10	0.72	1.56	0.20	0.15	1.38
Theory of constraints	A11	0.35	1.27	0.36	0.10	0.75
TRIZical Creanovatology	A12	0.39	1.13	0.31	0.07	1.41
Value stream mapping	A13	0.53	1.77	0.37	0.13	1.71

Stage 4 - The DEA model

DEA is a method based on linear programming applied to evaluate the relative efficiency of the decision units with the same duties. There are two basic variables in DEA: the input variables and the output variables. The inference of the input variables is that the less they are, the better they turn. The inference of the output variables is that the more, the better (Anvari et al., 2014). Thus, in this research, the time and cost variables are considered as the input, and the product design, process management, and innovation orientation as the output variables.

Max h

St:

$$\sum_{j=1}^{n} \mathbf{z_j} = 1$$

$$\sum_{j=1}^{n} \mathbf{z_j\, y_j^g \geq h y_0^g}$$

$$\sum_{j=1}^{n} \mathbf{z_j\, y_j^b \geq h y_0^b}$$

$$\sum_{j=1}^{n} \mathbf{z_j\, x_j \leq x_0}$$

$z_j \geq 0$, n= 1, 2, … , n

Y: Efficiency value for decision units

$\mathbf{x_{ij}}$: Input variable of the decision units

$\mathbf{y_{rj}}$: Output variable of decision units

n: Number of decision units

h: Relative efficiency score

$\mathbf{z_j}$: Weighted value of the and output variables

According to the above formula and the previous stages of the research (Table 7), the linear model is formed. 13 models are produced based on 13 alternatives, five criteria (two inputs and three outputs), and five variables with the objective of efficiency maximization. Each model has an objective function, 14 constraints, and five non-negative variables. All the above models are separately solved using Lingo software which is as follows (Table 8):

Table 8. Results from linear programming models

Alternatives		**Efficiency**	**Rank**
5W2H	A1	1.000000	1
Intellectual maps	A2	0.9824375	2
Lateral thinking	A3	0.8958819	6
Kano model	A4	0.8799189	7
Voice of customer	A5	0.9148000	5
Making pattern	A6	1.000000	1
Seven old tools of QC	A7	0.7851885	10
Seven new tools of management and planning	A8	1.000000	1
Development of quality performance	A9	0.8677083	9
SWOT analysis	A10	0.9607024	4
Theory of constraints	A11	0.9799013	3
TRIZical Creanovatology	A12	1.000000	1
Value stream mapping	A13	0.8711312	8

It is concluded that four TQM techniques, including 5W2H, benchmarking, seven management and planning tools, and innovative problem solving, with an efficiency of 1, are in the highest ranking. The rest of the tools, with an efficiency of less than 1, are not efficient. It includes mind maps, theory of constraints, SWOT analysis, voice of the customer, lateral thinking, Kano model, value stream mapping, QFD, and seven QC tools.

4. DISCUSSION AND CONCLUSION

In any situation, there is a need and necessity to have a performance evaluation system in an organization. This has demonstrated that the lack of an evaluation system is known as a symptom of disease for the organization. Hence, performance evaluation of the companies against the innovation performance criteria is necessary to present solutions to improve competitive advantage. In general, this research was carried out with the following three objectives: identifying the requirements for the realization of innovation, identifying the tools and techniques of TQM for competitive advantage, and investigating the maximization of innovation in the framework of TQM, examining the research's general purpose on the relationship between TQM and innovation.

In the literature review, it turned out that the requirements of innovation realization include: Conformity time, Cost of implementation, New Product Design, Process management, Innovation orientation (Table 2), and 13 TQM practices influencing innovation realization (Table 1). Furthermore, using the FAHP and DEA, all these factors affect innovation realization. Therefore, it implies that to achieve the maximum competitive advantage; TQM could be employed; since it provides a platform to attain innovation more easily. It also turned out that, to maximize innovation, an organization must consider the complex organizational conditions, TQM techniques, and their capabilities to realize innovation.

According to Table 8, the alternatives with DMU=1 are efficient. Namely, their role in realizing the innovation performance criteria is high and ideal. The alternatives with DMU<1 are not efficient. Namely, their role in realizing the innovation performance criteria is not high and ideal. Therefore, it can be said that 5W2H techniques, benchmarking, seven management tools, and innovative problem solving are of particular importance for the better realization of innovation performance.

Finding factors or tools that are effective in realizing competitive and relative advantage is of particular interest to companies because it is often unclear which factors have an effective role in their success. Furthermore, the results of this research, stating that TQM has a positive effect on innovation, support the ideas and research works of many researchers (e.g., Prajogo and Sohal, 2003 and 2004; Abrunhosa and Sá, 2008; López-Mielgo et al., 2009; Long et al., 2015; Aminbeidokhti et al., 2016; Zhang et al., 2016; Li et al., 2018; Antunes et al., 2021; Shuaib et al. 2021; Fernandes and Fernandez, 2022; Sila, 2022). It also supports the ideas of those (e.g., McAdam and Armstrong, 2001; Prajogo and Sohal, 2006; Perdomo-Ortiz et al., 2006; Pekovic and Galia, 2009; Yusr, 2016; Honarpour et al., 2018; Tarí and García-Fernández, 2018; Zhou et al., 2018; Lebedeva et al., 2019) who consider TQM as the pioneer of and called for innovation, claiming that simultaneous use of innovation and quality leads to enhanced organizational performance.In conclusion, Abrunhosa and Sá (2008), Lam et al. (2012), and Zhou et al. (2018) indicate that the execution of TQM principles promises innovation. Therefore, with continuous improvement and innovation, TQM, as a solution leading to customer satisfaction (Lam et al., 2012), stabilizes the model, which states how process innovation interacts and relates. The proposed model (Figure 1), developed in this regard, could be a sample and a solution for the companies mentioned above and similar ones; and even efficient for other industries.

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