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The Effects of TQM Practices on Innovation Using an ISM/Fuzzy-ANP Approach

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Abstract: The purpose of this study is to evaluate the effect of Total Quality Management (TQM) on each other and to find out which TQM practices are directly or indirectly related to the different types of innovation. To analyze the data, methods of Interpretive Structural Modelling (ISM) and Fuzzy Analytic Network Process (F-ANP) were used. The instrument used for data collection is the questionnaire consistent with the analysis framework. The population of the study were 30 experts of Farassan industrial-manufacturing company.The findings showed that the set of TQM practices through continuous improvement positively associated with innovation types. The TQM practices are closely connected with each other. In order to achieve innovation, the importance of all practices as an integrated system should be considered. Strategies and key elements of TQM have the ability to deal with challenges in today competitive economy because with the key principles, integrated and universal, it can help to open new horizons for development and transition towards quality management, improvement of processes and innovative approaches in products and processes. In the current turbulent time, companies and organizations require the application of tools, models to take advantage of all the features of TQM and reach into innovation. In doing so, this study presents a model and a road map to achieve TQM and innovation andclarifies to what extent TQM practices affected innovation.

Key words: TQM, innovation, F-ANP, ISM, strategies

INTRODUCTION

In a global market, firms should have the ability to identify new chances and to reconfigure and shield technologies, competences, knowledge assets and complementary assets to accomplish a sustainable, competitive advantage (Teece, 2000). In order to compete in a changing market, companies must improve the quality and innovation. Over the last 30 year, innovation has caught the attention of researchers and practitioners (Kim *et al*., 2012). In a turbulent economic environment, innovation is a strategic driver in seizing new opportunities and protecting knowledge assets (Hurmelinna *et al*., 2008). Specifically, innovation plays a key role in providing unique products and services by creating greater value than was previously recognized and establishing entry barriers (Montes *et al*., 2005). The importance of innovation has motivated researchers to identify the various driving forces of innovation (Becheikh *et al*., 2006).

Total Quality Management (TQM) is described as a collective, interlinked system of quality practices that is associated with organizational performance. Total quality management is a systematic quality improvement approach for firm-wide management for the purpose of improving performance in terms of quality, productivity, customer satisfaction and profitability (Sadikoglu and Zehir, 2010). Some researchers contend that Quality Management (QM) could be one of the prerequisites of innovation (Hoang *et al*., 2006). Since TQM practices have been embraced by many firms around the world for decades, they have earned the attention of many researchers from diverse areas) (Sadikogluand Zehir, 2010).

Since the early 2000s, researchers have conducted empirical studies on the relationship between QM and innovation. Earlier studies on the relationship between QM and innovation have provided inconsistent findings. Some found that QM practices are positively related to innovation (Perdomo *et al*., 2006; Martinez and Lorente, 2008) whereas others concluded that there is no evidence linking QM activities and innovation (Singh and Smith, 2004; Moura and Abrunhosa and Sa, 2008; Prajogo and Sohal, 2004). Researchers have tended to identify whether the implementation of QM practices is positively related to innovation (Abrunhosa and Sa, 2008; Martinez and Lorente, 2008; Hoang *et al*., 2006) or which QM practice is directly related to innovation (Moura and Abrunhosa, 2007; Prajogo and Sohal, 2004).

The multidimensional types of innovation need to be tested to correctly understand the real value of QM on

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innovation (Kim *et al.*, 2012), however, researchers were limited to assessing only a few types of innovation. Some studies examined a single type of innovation such as process innovation (Abrunhosa and Sa, 2008) or product innovation (Prajogo and Sohal, 2004) whereas others explored both process and product innovation (Feng *et al.*, 2006; Martinez and Lorente, 2008).

In the same vein, this study will investigate the interrelationship among TQM practices, as well as their relationships to various types of innovation. The ultimate purpose is to reach a practical framework underlying a model offered to the Farassan manufacturing and industrial company in Iran in which the research was conducted as well as to other organizations and enterprises. Furthermore, this study was guided by expert's opinions, knowledge and skills of the company under study. As the ultimate purpose of the research, it is important to clarify to what extent TQM practices affected innovation and/or contributed to it. To accomplish this, the study primarily addresses theoretical foundations of TQM, innovation and their interrelationships and then focuses on research purposes and methodology. Finally, based on using ISM/Fuzzy ANP approach, analysis of the results and findings are presented, accompanied with some Guidelines for the industry.

Literature review

Total quality management: TQM can be defined as a holistic management philosophy that strives for continuous improvement in all functions of an organization and it can be achieved only if the total quality concept is utilized from the acquisition of resources to customer service after the sale (Kaynak and Hartley, 2005). Researchers emphasize that it is necessary for firms to define and develop QM practices that can assist a multi-dimensional management philosophy. QM practices refer to critical activities that are expected to lead, directly or indirectly to improved quality performance and competitive advantage (Kim *et al.*, 2012). The critical factors of TQM can be described as best practices or ways in which "firms and their employees undertake business activities in all key processes": leadership, planning, customers, suppliers, community relations, production and supply of products and services and the use of benchmarking (Sila and Ebrahimpour, 2005).

Acknowledging the fact that the TQM construct is defined in numerous ways in previous empirical studies by Prajogo and Sohal (2006). Broadly speaking, the literature shows that Saraph *et al.* (1989) research was one of the very first investigations of the elements of quality management and its practices. They proposed eight key factors for TQM including management leadership, quality data and reporting, training, employee relations, product/service design, supplier quality management, process management and strategic planning (Kaynak, 2003). Following Saraph *et al.* (1989), other researchers such as Flynn *et al.* (1994), Ahire *et al.* (1996), Black and Porter (1996) and Kaynak (2003) sought to identify the key elements of TQM, developing measurement tools for analyzing its practices. A total of 45 different critical factors of QM have been developed by the researchers who conducted research in different parts of the world. In other words, each researcher provided and discussed his or her own set of critical factors. Of the 45 different critical factors developed by the researchers, 9 were found to be the most frequently considered factors. These 9 critical factors, ranked from the highest level to the lowest level of popularity are as follows: Top management support, customer focus, employee involvement, employee training, product design, supplier quality management, quality information availability, quality information usage and benchmarking (Shan *et al.*, 2013). Accordingly, this study after a detailed overview of the literature, consideredten critical factors as key factors of total quality management. These factors are described in the following:

Management leadership: Management leadership refers to the extent to which top management establishes quality goals and strategies, allocates resources, participates in quality improvement efforts and evaluates quality performance (Saraph *et al.*, 1989). Management leadership is a minimum requirement to adopt and maintain other QM practices. Without strong top management support, it may be impossible to build an effective environment for QM and produce benefits from other QM practices (Kim *et al.*, 2012). According to the empirical studies, management leadership is positively related to other QM practices, especially training, employee relations, supplier quality management, customer relations and product design (Flynn *et al.*, 1995; Ravichandran and Rai, 2000; Kaynak, 2003; Sila and Ebrahimpour, 2005; Ahire and Ravichandran, 2000; Zu *et al.*, 2008).

Employee relations: The success of QM implementation can be ensured if responsibility for quality is extended toall employees and all departments in an organization (Mehra *et al.*, 2001). According to empirical studies including Flynn *et al.* (1995), Kaynak (2003) and Ravichandran and Rai (2000) employee involvement in quality efforts plays a key role in dealing with quality data, designing products and managing processes. Organizations should focus on encouraging employees to be involved in quality efforts and to be motivated and e mpowered. This is because empowered employees demonstrate a strong sense of ownership (Kim *et al*., 2012).

Customer relations: A customer is one of the key decision makers in determining product specifications. Having a close association with customers requires a firm to promptly update accurate information about customer demands, allowing the firm to reduce redesign cost and time, to deliver high quality products and to satisfy customers. Existing empirical studies have proven that a close relationship with customers positively contributes to quality data (Zu *et al*., 2008).

Training: Training refers to the extent to which an organization provides employees with statistical training, job-related skill training and quality-oriented training such as quality techniques (Saraph *et al*., 1989). Researchers have confirmed that training is a basic factor in the success of QM implementation. Appropriate training offers opportunities for improving teamwork, reducing errors and enhancing job satisfaction. In particular, training is directly related to the way employees research (Mehra *et al*., 2001).

Strategic planning: Strategic planning involves three areas of mission and policy, strategy development and strategy deployment (Sila and Ebrahimpour, 2005). Based on mission and policy, organizations has a clear focus on quality (Carman, 1993) and they take a clear long-term view on how to achieve our goals (Anderson *et al*., 1995, 2008). In strategy development organization set and review their short and long-term goals through a comprehensive planning process (Samson and Terziovski, 1999) and allocate sufficient resources for the successful implementation of strategies focused on quality. Finally based on Strategy deployment at each level of the company, teams are assigned to set objectives and devise action plans and have an overall action plan measurement (Sila and Ebrahimpour, 2005).

Quality data and reporting: Quality data and reporting refers to the extent to which an organization uses quality data, regularly measures quality and evaluates employees based on quality performance (Kim *et al*., 2012). Studies have proved that managing quality data offers opportunities for establishing a strategic relationship with suppliers, designing a new product and improving process (Kaynak, 2003). Empirical studies have showed that quality data can play a vital role in achieving innovation. Miller (1995) in a survey of 45 large multinational firms, concluded that managing quality data is the most important QM practice that can be applicable to innovative activities.

Supplier quality management: Supplier quality management refers to the extent to which an organization depends on fewer suppliers, is interdependent with suppliers, emphasizes quality rather than price in purchasing policy and supports suppliers in product development (Saraph *et al*., 1989). Empirical studies have proven that if a company has a strategic partnership with suppliers, the company may generate a positive performance enhancement in product design and process management (Kaynak, 2003; Zu *et al*., 2008).

Process management: Process management is based on the notion that a firm's capability is embedded in processes and can be strengthened through effective management of processes (Das and Joshi, 2011). Managing processes encourage firms to develop best practices, called routines that can be used to establish a learning base and support innovative activities (Perdomo *et al*., 2006). Routines include diverse procedures and skills that assist employees in improving their administrative systems or functions. Several empirical studies have shown that organizational routines lead to incremental learning and innovation (Hoang *et al*., 2006; Perdomo *et al*., 2006).

Product/service design: Product/service design is defined as the extent to which all departments in an organization are involved in design reviews the extent to which an organization emphasizes productivity, the extent to which an organization makes specifications clear and the extent to which an organization highlights quality (Saraph *et al*., 1989). Empirical studies also indicate that product/service design can facilitate process management (Ahire and Dreyfus, 2000; Kaynak, 2003).

Continuous improvement: Continuous improvement refers to the propensity of the organization to pursue incremental and innovative improvements of its processes, products and services (Rungtusanatham *et al*., 1998). Continuous improvement refers to searching for never-ending improvements and developing processes to find better methods in the process of converting inputs into outputs. By improving inter linked processes, a firm can do a better job of satisfying customer's needs and expectations (Sadikoglu and Zehir, 2010).

Innovation: Innovation refers to new applications of knowledge, ideas, methods and skills that can generate unique capabilities and leverage an organization's competitiveness (Andersson *et al*., 2008). Researchers have explored the classification of innovation in different ways (Di Benedetto *et al*., 2008). In order to distinguish the five types of innovation we need to discuss the differences between administrative and technological innovation (Damanpour, 1987). Administrative innovation refers to the application of new ideas to improve organizational structures and systems and processes pertaining to the social structure of an organization (Weerawardena, 2003). In contrast, technological innovation is defined as the adoption of new technologies that are integrated into products or processes. Administrative innovation is often triggered by internal needs for structuring and coordination while technological innovation mainly responds to environmental factors such as uncertain market conditions or technical knowledge.

Depending on the degree and subject of innovation, technological innovation is further classified into incremental and radical innovation and product and process innovation (Kim *et al*., 2012). Technological innovation can be divided into incremental and radical innovation when considering the following features of innovation: the level of change (minor vs. major), a target customer or market (existing vs. new) and the level of risk (low vs. high).

Incremental innovation refers to minor changes of existing technologies in terms of design, function, price, quantity and features to meet the needs of existing customers while radical innovation is defined as the adoption of new technologies to create a demand not yet recognized by customers and markets (Kim *et al*., 2012). Product innovation is concerned with generating ideas or with the creation of something entirely new that is reflected in changes in the end product or service (Yang *et al*., 2009) whereas process innovation represents changes in the way firms produce end products or services through the diffusion or adoption of an innovation developed elsewhere (Yang *et al*. ,2009).

It is necessary to understand a type of innovation and its different features because a specific type of innovation requires an organization to demonstrate unique and sophisticated responses. Empirical studies on innovation have explored five types of innovation: incremental product, incremental process,radical product, radical process and administrative (Vermeulen, 2005; Di Benedetto *et al*., 2008). Investigating the various types of innovation helps practitioners break down their overall strategies on innovation into a particular type of innovation area and efficiently allocate resources for aspecific type of innovation (Kim *et al*., 2012). Thus, this study applies the five types of innovation to analyze correlations with QM practices.

MATERIALS AND METHODS

Sample and data collection: The main purpose of the present study was to investigate the relationship between the indicators of TQM and those of innovation. To accomplish this major objective, there were also some peripheral purposes as follows:

- To identify the relationship between TQM practices and innovation and to determine the influence of the former on the latter (direct or indirect)
- To identify the relationships among TQM indicators and their influence on each other

This study examines the effects of TQM practices on innovation by using an ISM/Fuzzy-ANP approach in Farassan manufacturing and industrial company. The data for analysis were collected through the opinions of Farassan Industry experts including managers, intermediate managers and professional employees. The population included 30 specialists and experts. Out of the present experts, 21 ones were selected as the sample. To primarily determine the effects of TQM practices on innovation, the standard ISM questionnaire was used with the purpose of making pair-wise comparisons between factors. Then to determine the importance coefficient of all of the indicators of TQM and those of innovation, a pair-wise comparison 9-unit scale of Fuzzy ANP (F-ANP) questionnaire was formulated.

Interpretive Structural Modeling (ISM): Interpretive structural modeling is an appropriate technique for analyzing the effect of an element on others. This method investigate the type and the direction of complex relationship between the elements in a given system i.e., this is a tool that makes it possible to overcome the complexity between elements (Ravi and Shankar, 2005). Interpretive Structural Modeling (ISM) can change the vague and abstract models into visible and clear models which are really helpful to reach the goals. This approach is an interactive learning process in which a group of different elements is made in a comprehensive systematic framework (Agarwal *et al*., 2007). Thakkar *et al*. (2008) discussed that, ISM is a modeling technique that can show specific relationship with elements and the whole system structure by studying a graph. Moreover, it is a good way to identify and evaluate the relationship between specific elements in a given problem. Based on literature, the various steps involved in ISM technique are as follows:

Table 1: The dimensions and factors

Dimensions	Factors
D1: TQM	F1: Management leadership
	F2: Training
	F3: Employee relations
	F4: Supplier quality management
	F5: Customer relations
	F6: Strategic planning
	F7: Product/service design
	F8: Process management
	F9: Quality data and reporting
	F10: Continuous improvement
D2: Innovation	F11:Radical product innovation
	F12:Radical process innovation
	F13:Incremental product innovation
	F14:Incremental process innovation
	F15:Administrative innovation

Step 1: Determining of elements relevant to the problem. Starting point of ISM is the identification of elements relevant to the problem. In this research by using empirical stadies, the effective factors on total quality management practices and innovation in Farassan industry determined and these factors are those as the same elements about applying ISM problem. Table 1 describes the dimensions and factors under study.

Step 2; Construction of Structural Self-Interaction Matrix (SSIM): During this phase, the participants must decide upon the pairwise relationship between the elements. Keeping in mind the contextual relationship for each element, the existence of a relation between any two sub-elements (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of the relationship between the elements i and j:

- V: For the relation from i to j but not in both directions
- A: For the relation from j to I but not in both directions
- X: For both direction relations from i to j and j to i
- O: If the relation between the elements does not appear to be valid

In doing so, based on the experts' maximum response to each of the paired comparisons, the direction of relationship was identified for each of the paired comparisons and the Structural Self-interaction Matrix (SSIM) was created (Table 2).

Step 3: Developing aninitial reachability matrix and checking for transitivity. This phase is concerned with the construction of the reachability matrix. It is a binary matrix since the entry V, A, X and O of the SSIM are converted into 1 and 0 as per the following rules:

- If the (I, j) entry in the SSIM is V, then the (I, j) February 23, 2017 entry in the reachability matrix becomes 1 and the (j, i)entry becomes 0
- If the (I, j) entry in the SSIM is A, then the (I, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1
- If the (I, j) entry in the SSIM is X, then both the (I, j) and (j, i) entries of the reachability matrix become 1
- If the (I, j) entry of the SSIM is O, then both the (I, j) and (j, i) entries of the reachability matrix become 0

Table 3 shows the initial reachability matrix in this study transitivity is a basic assumption in ISM that leads to the final reachability matrix. It states that if element A is related to B and B is related to C, it may be inferred that A is related to C. Indirect relationships can be found by raising the initial reachability matrix to successive powers until no new entries are obtained. That is until the steady-state condition is reached i.e.:

$$M^{n-1} < M^{n} = M^{n+1}$$

In this study at the end of this stage, the final reachability matrix after three stages was created and its transitivity was checked. The relationships established after the transitivity check were marked by "*" in Table 4. The final reachability matrix depicts the driving and the dependence power of each risk. Driving power of each risk is the total number of risks (including themselves) which it affects i.e., the sum of interactions in the rows. Conversely, dependence power of each risk is the total number of risks (including themselves) by which it is affected, i.e., the sum of interactions in the columns.

Step 4: Level partitioning of reachability matrix: The purpose of this phase is to facilitate the construction of the digraph from the reachability matrix. From the final reachability matrix, the reachability and antecedent set for each factor are found. The reachability set consists of the element itself and the other elements that it may impact, whereas the antecedent set consists of the element itself and the other elements that may impact it. Thereafter, the intersection of these sets is derived for all the factors i.e., the common elements in both sets is derived for each factor. The factors for whom the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy (Faisal *et al*., 2007). The top-level element has no relation to any other elements above their own level. Once top-level elements are identified they are separated out from the other elements. Then, the same process undergoes iterations till the level of all elements is achieved. These identified levels help in building the

Table 2: SSIM Matrix

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1															
F2		V	V	V	V	V	V	O	O	O	V	V	V	V	V
F3			V	O	O	O	O	O	V	V	V	V	V	V	V
F4				O	O	O	V	V	V	V	V	V	V	V	V
F5					O	O	V	V	A	O	O	O	O	O	O
F6						A	O	O	V	O	O	O	O	O	O
F7							O	O	A	O	O	O	O	O	O
F8								V	A	V	V	V	V	V	V
F9									A	V	V	V	V	V	V
F10										V	V	V	V	V	V
F11											V	V	V	V	V
F12												O	O	O	O
F13													O	O	O
F14														O	O
F15															O

Table 3: Initial reachability matrix

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1
F2	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1
F3	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1
F4	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0
F5	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
F6	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1
F8	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1
F9	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1
F10	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
F11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
F12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
F13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
F15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4: Final reachability matrix

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	Driving power
F1	1	1	1	1	1	1	1	1*	1*	1*	1	1	1	1	1	15
F2	0	1	1	1*	1*	1*	1*	1*	1	1	1	1	1	1	1	14
F3	0	0	1	1*	1*	1*	1	1	1	1	1	1	1	1	1	13
F4	0	0	0	1	0	0	1	1	0	1*	1*	1*	1*	1*	1*	9
F5	0	0	0	1*	1	1*	1*	1*	1	1*	1*	1*	1*	1*	1*	12
F6	0	0	0	1*	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	12
F7	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	8
F8	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	7
F9	0	0	0	1	1*	1	1	1	1	1	1	1	1	1	1	12
F10	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	6
F11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
F12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
F13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
F14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
F15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence power	1	2	3	7	6	6	8	9	6	10	11	11	11	11	11	

digraph and final ISM Model. As can be seen in Table 5, the reachability set and the intersection set of factors 11-15 became equal. Therefore, these factors shaped the first level of the ISM hierarchy. Then, these factors were omitted from the row and column of the next table and all other stages were completed following the same pattern. In this study, the process was completed through 9 stages. Table 6 shows the final leveling of the factors.

Step 5: Building the ISM Model: From the final reachability matrix, the structural model is generated. If there is a relationship between the factored i and j, this is shown by an arrow which points from i to j. This graph is called a directed graph or digraph. The developed ISM has no cycles or feedbacks. Elements are related in pure hierarchical pattern. In this final step, the ISM model was represented as a directed graph by placing the factors in their corresponding levels. The factors ranked in the first level were placed at the lowest parts of the ISM Model

Table 5: Levels of critical factors, iteration 1

Factors	Reachability set	Antecedent set	Intersection	Level
F1	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1	F1	
F2	F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1, F2	F2	
F3	F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1, F2, F3	F3	
F4	F4, F7, F8, F10, F11, F12, F13, F14, F15	F1, F2, F3, F4, F5, F6, F9	F4	
F5	F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1, F2, F3, F5, F6, F9	F5, F6, F9	
F6	F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1, F2, F3, F5, F6, F9	F5, F6, F9	
F7	F7, F8, F10, F11, F12, F13, F14, F15	F1, F2, F3, F4, F5, F6, F7, F9	F7	
F8	F8, F10, F11, F12, F13, F14, F15	F1, F2, F3, F4, F5, F6, F7, F8, F9	F8	
F9	F4, F5, F6, F7, F8, F9, F10, F11, F12, F13, F14, F15	F1, F2, F3, F5, F6, F9	F5, F6, F9	
F10	F10, F11, F12, F13, F14, F15	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10	F10	
F11	F11	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11	F11	1
F12	F12	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F12	F12	1
F13	F13	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F13	F13	1
F14	F14	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F14	F14	1
F15	F15	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F15	F15	1

Table 6: Levels of factors

Factors	Reachability set	Antecedent set	Intersection	Level
F1	F1	F1	F1	9
F2	F2	F1, F2	F2	8
F3	F3	F1, F2, F3	F3	7
F4	F4	F1, F2, F3, F4, F5, F6, F9	F4	5
F5	F5, F6, F9	F1, F2, F3, F5, F6, F9	F5, F6, F9	6
F6	F5, F6, F9	F1, F2, F3, F5, F6, F9	F5, F6, F9	6
F7	F7	F1, F2, F3, F4, F5, F6, F7, F9	F7	4
F8	F8	F1, F2, F3, F4, F5, F6, F7, F8, F9	F8	3
F9	F5, F6, F9	F1, F2, F3, F5, F6, F9	F5, F6, F9	6
F10	F10	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10	F10	2
F11	F11	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11	F11	1
F12	F12	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F12	F12	1
F13	F13	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F13	F13	1
F14	F14	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F14	F14	1
F15	F15	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F15	F15	1

hierarchy whereas the rest of the factors were placed at the higher levels. The factors placed at the lowest level of the ISM Model were those with the least driving power, while factors placed at the top level were interpreted as the ones with maximum driving power.

As the final derived model proposed in this study shows (Fig. 1) such factors as radical product innovation, radical process innovation, incremental product innovation, incremental process innovation and administrative innovation shaped the base of the ISM hierarchy and accordingly they are regarded as the factors with the least driving power. Also, the factor management leadership topped the hierarchy, showing the highest degree of driving power.

According to the notion of transitivity in logic if (i, j) = 1 and (j, k) = 1 then (i, k) = 1. That is, these criteria can indirectly influence each other. To reduce the complexity of the model and to put emphasis on more powerful (inter) relationships among TQM practices as well as between TQM practices and innovation, the variables indirectly associated to each other (based on transitivity) were removed from the model.

Step 6: MICMAC analysis: The objective of the MICMAC analysis in this study is identification and analysis the elements according to their driving power and dependence of effective factors on security. MICMAC is an indirect classification method to critically analyze the scope of each element. All elements are divided into four groups of factors:

Group 1: Autonomous elements that have weak driving power and weak dependence.

Group 2: Dependent elements that have weak driving power and strong dependence.

Group 3: Linkage elements that have strong driving power and strong dependence.

Group 4: Independent elements that have strong driving power but poor dependence. Figure 2 shows MICMAC analysis based on the results arising from the reachability matrix. As this analysis depicts such variables as management leadership, training, employ relations, customer relations, strategic planning and quality data and reporting were recognized as independent variables. This category as mentioned before, involves variables with a high driving power but weak dependence. Furthermore, among these variables management leadership showed the highest degree of driving power.

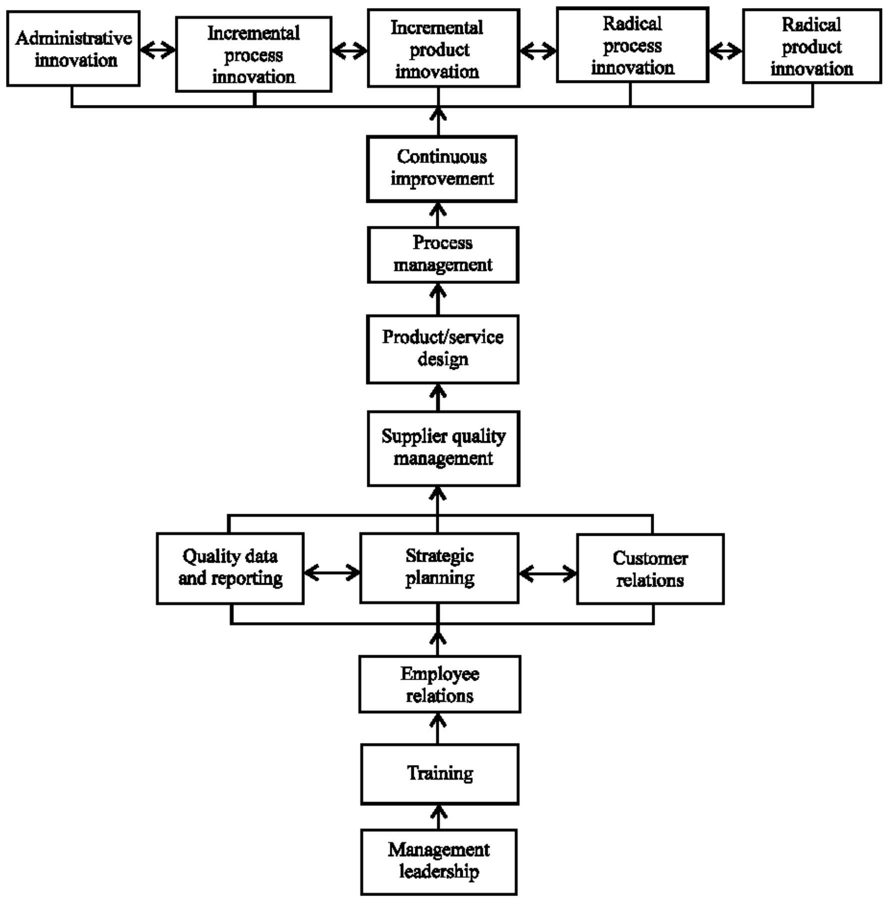

Fig. 1: ISM directed graph

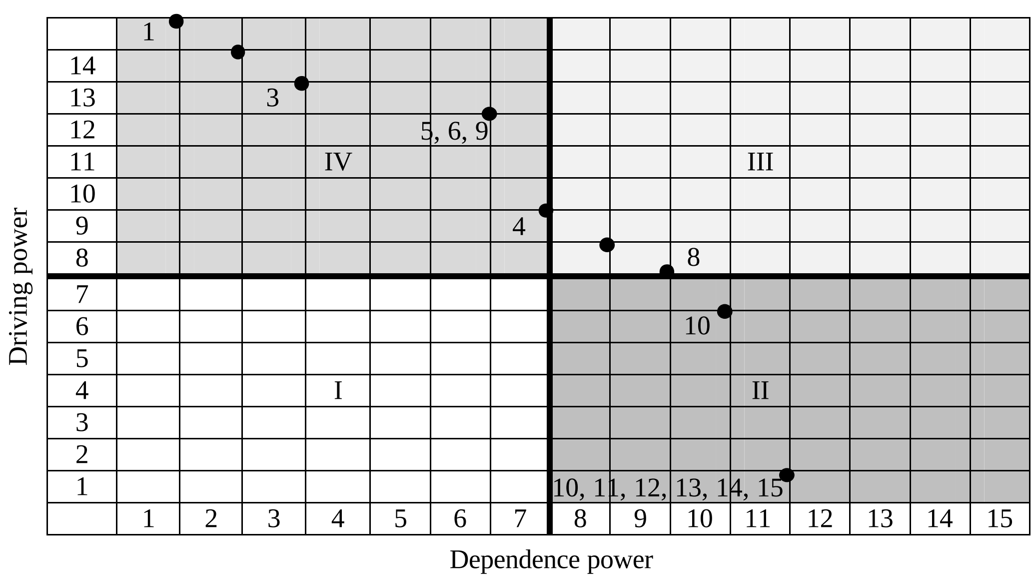

Fig. 2: Driving power and dependence graph

Such variables as supplier quality management, product design and process management were also observed as Linkagevariables. This set of variables showed a high driving power and a strong dependence. Finally, the factors, continuous improvement and types of innovation were recognized as dependent variables which are normally engaged in the outcome. For these factors to come into existence, numerous elements are involved, although they cannot per se bring about other factors.

RESULTS AND DISCUSSION

Fuzzy Analytical Network Process (FANP): The Fuzzy Analytical Network Process (FANP) is an advanced model to build and analyze of decision making. This model can compute the compatibility of judgments and flexibility in several levels of judgment criteria. Fuzzy Analytical Network Process Model is in fact the modified model of Analytical Hierarchy Process (AHP) technique in which the existing assumption in AHP Model does not satisfy based on lack of relationship among various levels of decision making. The experts use their own competencies and mental capabilities to conduct comparison in this technique but this point should be noticed that traditional AHP may not perfectly reflect human's thinking style. In better words, utilization of fuzzy sets is more compatible to verbal and sometimes human ambiguous expressions and therefore, it is better to predict for long run and decision making in real world by means of fuzzy sets (using fuzzy numbers). Van Laarhoven and Pedrycz (1983) two Dutch researchers called Laarhoven and Pedrycz have suggested a method for Fuzzy Analytical Hierarchy Process (FAHP) that was based on logarithmic least square technique. In 1996, another method was posited by chang under title of extent analysis method. The numbers used in this technique were triangular fuzzy numbers (Chang *et al.*, 2009).

From general perspective, ANP includes two phases: the first is the formation or building of network and the second is the calculation of priorities of indices. To form structure of problem, all interactions between indices should be considered.

If factor Y is dependent on factor X this relation is shown by an arrow from X-Y (X→Y). All of these relations and correlation are evaluated by means of pairwise comparisons and a technique called super-matrix. The supper matrix includes a matrix composed of the effects among components of the network in which these relations are derived from priority vectors. Super matrix consists of a hierarchy with three levels as follows:

$$W = \begin{bmatrix} 0 & 0 & 0 \\ W_1 & W_3 & 0 \\ 0 & W_2 & W_4 \end{bmatrix}$$

Where:

- W_1 = The vector that indicates the effect of target on indices. In other words, it shows the importance of these indices
- W_2 = A matrix that indicates the rate of realization for each of indices
- W_3 = Shows the internal relations between indices
- W_4 = A matrix which indicates the internal relations among choices

And at the end, the multiplication product of internal relations among W_3 indices may be derived for calculation of correlation priority of indices:

$$W_C = W_3 \times W_1$$

The following steps should be taken to calculate weight of importance of indices in FANP.

First step; Formation of hierarchical structure: A general schema is presented from target levels and criteria so that initially the target is inscribed at first level and then criteria at the second level and if there are some choices they will be placed at third level.

Second step; Formation of pairwise comparisons matrix: In this phase, the relative importance of all criteria and dimensions will be compared to each other.

Third step: Calculation of triangular fuzzy numbers: With respect to relative importance of the computed values in previous phase triangular fuzzy numbers are calculated to integrate all comments from experts. Triangular fuzzy number set is defined as follows:

$$\tilde{a}_{ij} = (\alpha_{ij}, \beta_{ij}, \delta_{ij})$$

Where:

- $\tilde{a}_{ij}$ = Denotes the set of triangular fuzzy numbers
- α_{ij} = The lowest value of criterion j for dimension i
- β_{ij} = Geometric mean of criterion j for dimension i
- δ_{ij} = The highest value of criterion j for dimension i

Fourth step: Formation of reciprocal definite fuzzy matrix: The matrix set derived from fuzzy set is expressed as follows:

$$A = [\tilde{a}_{ij}]$$

$$\tilde{a}_{ij} = [\alpha_{ij}, \beta_{ij}, \delta_{ij}]$$

Where:

- α_{ij} = Represents $\alpha$is the geometric mean of criterion j for dimension i
- β_{ij} = represents β as the geometric mean of criterion j for dimension i
- δ_{ij} = Represents δ as the geometric mean of criterion j for dimension I

Fifth step: Calculation the weight of reciprocal definite fuzzy matrix. This step has been developed by and fuzzy weights were calculated by Li. This method is based on

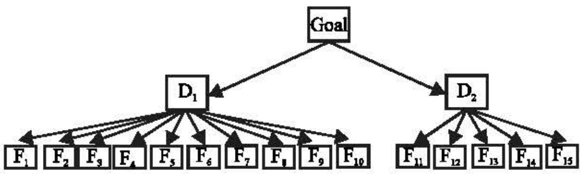

Fig. 3: Hierechical structure of ANP method

composition of expert's comment with geometric mean instead of embedding fuzzy numbers directly by the experts. Thus, not only the compatibility but descaling concept can be easily derived. At this phase, two geometric means of reciprocal definite triangular fuzzy numbers (Z_i) and fuzzy weight ($\tilde{\omega}_i$) are proposed and they can be acquired by means of the following equation:

$$Z_i=[\tilde{a}_{i1}\ \tilde{a}_{i2}...\ \tilde{a}_{i3}]^{1/n}$$
$$\tilde{\omega}_i=Z_i\ (Z_1\ Z_2...Z_n)^{-1}$$
$$\tilde{a}_1\times\tilde{a}_2=(\alpha_1\times\alpha_2,\beta_1\times\beta_2,\delta_1\times\delta_2)$$
$$\tilde{a}_1+\tilde{a}_2=(\alpha_1+\alpha_2,\beta_1+\beta_2,\delta_1+\delta_2)$$
$$Z_1^{-1}=(\delta_1^{-1},\beta_1^{-1},\alpha_1^{-1})$$
$$\tilde{A}_1^{1/n}=\{\alpha_1^{1/n},\beta_1^{1/n},\delta_1^{1/n}\}$$

Sixth step: Defuzzification: With respect to the given weights, it is seen that these weights possess fuzzy value. Therefore, the non-fuzzy values should be derived for these weights by defuzzification process. Definite weight value W_i is computed by the following equation:

$$W_i=\frac{W_{\alpha i}+W_{\beta i}+W_{\delta i}}{3}$$

Where:

$W_{\alpha i}$ = Denotes final value of the lowest fuzzy weight
$W_{\beta i}$ = The final value for core data in fuzzy weight
$W_{\delta i}$ = Final weight of the highest value in fuzzy weight

Seventh step: Descaling: At this phase, the given weights are descaled by the following relation:

$$NW=\frac{W_i}{\sum_{i=1}^{n}W_i}$$

Eight step: Composition of hierarchy: It is only enough to pass through first to seventh phases to achieve the weights of the existing criteria at low level (step 1-7 are adequate to achieve the goals in this thesis). The weights of the existing criteria or sub-criteria at high level are derived by composition of weights with respect to the following equation. Therefore, the weight of all indexes at any level can be calculated by the following Equation:

$$N_{Wk}=N_{wi}\times N_{Wip}$$

Determining the weight of dimensions and factors using the FANP method

Forming the hierarchical structure of FANP: At this phase, a general schema from goal level, dimension level and factorlevel is presented. So, initially the dimensions such as TQM and Innovation is written at second level and then factors (TQM practices and innovation types) at third level. Figure 3 shows the hierarchical structure of fuzzy analytic network process in this study.

Forming the pairwise comparisons matrix: At this phase, the importance of all of the factors relative to each other was subjected to pair-wise comparison. Saaty's nine-point-scale pairwise comparison was used to prepare a questionnaire. Accordingly, the questionnaire including pair-wise comparisons was formulated in two ways:

Questionnaire containing pairwise comparisons yielding the importance coefficients for all factors relative to their dimensions: All of the factors of TQM were compared and ranked relative to TQM and similarly all of the factorsof innovation were compared and ranked relative to innovation

Questionnaire containing pairwise comparisons yielding the importance coefficients for all factors relative to a particular factor: Considering the final reachability matrix in ISM, the set of factors influencing a particular factor was subjected to pairwise comparison in order to rank the importance of the factors relative to the particulate factor in question

Ranking the final weight of dimensions and factors: After taking fuzzy ANP steps from 1-7 for all the factors relative to their dimensions (TQM or innovation) and for factors relative to a particular factor, the weight matrix for factors relative to each other and also the factors weight matrix relative to their dimensions are shaped. Table 7 shows the weighted super matrix for all factors:

As Table 7 describe, the weights of innovation factors were turned into 0. The reason for this is the nature of the research topic itself as our goal was to investigate the effect of TQM practices on innovation. As

Table 7: Weighted supermatrix

	Dimentions		Factors														
Factors goal	D1	D2	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
D1																	
D2																	
F1	0.150			1	0.54	0.17	0.250	0.226	0.17	0.043	0.200	0.052	0.120	0.117	0.104	0.112	0.130
F2	0.110				0.46	0.16	0.250	0.210	0.13	0.038	0.248	0.135	0.095	0.098	0.098	0.097	0.111
F3	0.061					0.17	0.250	0.208	0.12	0.158	0.186	0.112	0.071	0.085	0.091	0.085	0.114
F4	0.081								0.17	0.173		0.095	0.090	0.068	0.089	0.091	0.080
F5	0.109					0.17		0.192	0.12	0.114	0.175	0.102	0.098	0.081	0.096	0.095	0.083
F6	0.099					0.17	0.247		0.13	0.129	0.180	0.112	0.100	0.102	0.097	0.103	0.100
F7	0.089									0.163		0.123	0.120	0.114	0.118	0.093	0.090
F8	0.101											0.143	0.100	0.122	0.100	0.121	0.120
F9	0.103					0.15		0.164	0.16	0.18		0.124	0.010	0.103	0.103	0.098	0.040
F10	0.092												0.099	0.108	0.104	0.104	0.110
F11		0.179															
F12		0.216															
F13		0.169															
F14		0.233															
F15		0.203															

Table 8: Final weight of TQM factors

Factors	Final weight	Ranking
Management leadership(F1)	0.202	1
Training (F2)	0.132	2
Employee relations (F3)	0.113	3
Supplier quality management (F4)	0.069	9
Costumer relations (F5)	0.094	5
Strategic planning (F6)	0.107	4
Product/service design (F7)	0.074	7
Process management (F8)	0.070	8
Quality data and reporting (F9)	0.080	6
Continuous improvement (F10)	0.058	10

a result, considering the conceptual model of the research, we did not consider the hypothetical relationship among different types of innovation thus, not including any instru ments in the ISM questionnaire for investigating the interrelationships among types of innovation. Thus, the values of types of innovation (radical product innovation, radical process innovation, incremental product innovation, incremental process innovation and administrative innovation) in the final reachability matrix were decided to be 0. Considering the final weights of innovation factors (Table 7) incremental process innovation (F14 = 0.233) and radical process innovation (F12 = 0.216) showed maximum importance coefficients, respectively. In contrast incremental product innovation (F13 = 0.169) and radical product innovation (F12 = 0.216) showed the least importance coefficients compared to the other factors.

After taking the foresaid steps in fuzzy analytic network process, two matrices (the factors weight matrix compared to each other and matrix of factors weight proportional to TQM) were acquired and then with respect to the defined relation in eighth step, two matrices should be multiplied to each other to measure the final weight of factors. After doing this operation, the acquired weights are normalized. Table 8 shows the final weights of TQM factors. As it depicts, management leadership (0.202), training (0.132), employee relations (0.113), strategic planning (0.107) and costumer relations (0.094) had the highest importance coefficients, respectively. Furthermore, supplier quality management (0.069) and continuous improvement (0.058) showed the least importance coefficients among the factors.

CONCLUSION

The present study investigated the impact of TQM practices on innovation using an integrated ISM/F-ANP approach, in Farassan industry, Iran. In this regard, to establish the relationships among the indicators of TQM and innovation the industry's expert opinions were relied on along with the application of ISM. The proposed model showed that the indicator, management leadership which was placed at the seventh level had the strongest driving power but the least dependence power. This set of variables influence the other variables associated with them and they should be considered as the priority of a system prior to its operation. On the other hand, indicators of innovation, including radical/incremental product innovation, radical/incremental process innovation and administrative innovation having the strongest dependence and the least driving power were found to be the most susceptible variables to influence.

The results arising from the ISM revealed that TQM practices had a positive and significant relationship to different types of innovation through an indirect association with the indicator continuous improvement. That is, the importance of QM practices are sharply interwoven with other TQM practices. As a result, if

Farassan manufacturing and industrial company would take into account a particular set of TQM practices, it could gain a special competitive advantage as far as innovative performance in concerned. Management leadership was indirectly and positively associated with innovation through other TQM practices including training, employee relations, suppler quality management, costumer relations, product/services design and so on.

Similarly, suppler quality management was indirectly related to innovation through product/services design. Process management was directly and positively associated radical, incremental and administrative innovations through the influence of other practices such as quality data and reporting, strategic planning, costumer relations, suppler quality management and product/service design. Therefore, it could be concluded that all of the TQM practices, except continuous improvement are indirectly associated with innovation.

Ultimately after the model was formulated, based on the relations established among the indicators and with a view to expert's opinions, F-ANP was employed to calculate the importance coefficient of each of the indicators. The importance coefficients obtained for TQM practices revealed that the indicator management leadership with the importance coefficient 0.202 was the most importance factors among all of the TQM practices. This finding was in line with the results arising from the ISM and confirmed them. More particularly, management leadership was the most influential variable among the entirety of variables and this finding was plausible as such variables which initiate the whole system performance had the maximum importance coefficient.

On the other hand, continuous improvement with the importance coefficient 0.058, showed the least importance among TQM practices. This low rate of importance, however would not justify that Farassan Industry should disregard or pay little attention to this variable but on the contrary, given the influential role of this variable in innovation types it could represent a special value.

Yet considering that in the system, TQM was placed in higher levels of association with other TQM practices and considering that it could ultimately affect innovation, it ironically scored lower than other quality-related variables. Furthermore, the observed coefficients of innovation types revealed that incremental innovation (0.233) and radical process innovation (0.216) had the maximum importance coefficient, respectively. In contrast, incremental product innovation (0.169) showed the minimum importance coefficient among the indicators. As a result, the company's increased attention to and concentration of processes as well as reform and optimization pertaining to them, might account for this finding.

IMPLICATIONS

Another importance implication of the study was that a mere emphasis on one or a limited number of TQM practices might not eventually lead to creative problem-solving and innovative performance. The final model proposed here unfolded that TQM practices were associated with each other. As a result, the proportion of improvement in the case of incremental, radical and administrative innovations cannot be solely attributed to continuous improvement and process management.

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