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DESIGNING A COMPETITIVE ADVANTAGE MODEL WITH TECHNOLOGY ORIENTED APPROACH USING FAHP TECHNIQUE: A CASE STUDY IN COIL INDUSTRY

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Abstract

One of the distinctive attributes of today's successful companies is having at least one competitive advantage in one known area. Technological competency is an important advantage which helps improve the firm's competitiveness. In fact, suitable use of new technologies can dramatically influence the innovation speed, decrease the time of product development cycle and also increase the rate of new product introduction. Firm-specific technological competencies help explain why a firm is different, how it changes over time, and whether it is capable of remaining competitive. In this study, technological competency factors (technology management, process technology, product technology) are prioritized according to the competitive advantage levels(customer satisfaction, brand reputation, new product introduction, market share) and competitive priorities (cost, price, quality, flexibility, time) using fuzzy Analytic hierarchy process (FAHP) with the aim of maximizing the nonfinancial performance at coil manufacture industry. The results indicate that within Iran coil industry, process technology is of greater importance than technology management and product technology.

Keywords: Technological competencies, Competitive priorities, Competitive advantage, Fuzzy analytic hierarchy process.

1. Introduction

Firms are confronted to great pressure in extending their new resources and reinforcing their competitive advantages. Competitive advantage is defined as the firm's ability to perform better than its competitors which may lead to higher level

Nomenclatures

GM	Geometric mean
k	Decision-maker number
$M_{g_i}^{i}$	Triangular fuzzy numbers
S_i	Fuzzy synthetic extent
$V(M_2 \geq M_1)$	Degree of possibility
W	Related weight to each criterion
W_i	Combined fuzzy weight is the decision factor from "k"
W_i^k	Fuzzy weight of decision factor is from decision–maker "k"

of profitability among rivals. Customer satisfaction, brand reputation, new product introduction and market share are among the countless criteria leading to gain competitive advantage [1]. Of all the environmental factors that influence the organization, technological capability is more prone to create long-term competitive advantage that must be considered by the firms [2].

To describe the concept of "competitive capability" in management area, terms such as competitive priorities or capabilities and collective competencies are commonly used. Competitive capability is defined as "real firm ability to compete with competitors at market" [3]. In other words, competitive capability refers to "the ability of the firm to offer products with peculiar performance, which can attract the orders from competitors toward the own firm". Producers need to gain, strengthen and protect some competitive capabilities to remain competitive in global markets.

Competitive capabilities include many factors or items such as low price, high product quality, time of delivery and offer, flexibility and cost of services to customers. Antonio et al. believe that the 5 competitive capabilities stated above, are the main keys to the firm's success [4].

The main theme of this study is to determine the factor's priority existing at the firms technological competency level (technology management, process technology, product technology) regarding two bundles of operational measures for the two strategic constructs of competitive advantages- customer satisfaction, brand reputation, new product introduction, market share- and the firm's competitive priorities - cost, price, quality, flexibility and time.

2. Technology: Definition and Model Building

Technology is defined as the procedures or ways of doing works which is most often made up of information or machinery. Also, it has been recognized as necessary skills and knowledge to produce goods and services which is the mixture of human insight, intelligence and natural rules [5]. Technology is also defined as a set of processes, tools, work methods, approaches and equipments used to produce the products and services [6].

Again, the final result of the AHP evaluation is a list of prioritized capabilities whose values indicate their relative importance to non-financial business performance. As mentioned earlier, most of the non-financial measures are qualitative, Fig. 1. This means that the pairwise comparisons of the non-financial measures mainly rely upon the subjective judgment of the decision-makers. If there is more than one decision-maker involved, the pairwise scores assigned to the criteria and capability alternatives should be based on the geometric mean of the individual scores.

Figure 2 illustrates an example of a non-financial evaluation model with single-leveled capability alternatives.

The conceptual model of this study, as presented in Fig. 3, is extracted from the models introduced by Erensal et al. [1] and Hafeez et al. [7]. The variables included in the first and second levels are taken from Hafeez et al. and Erensal et al. models. Furthermore, the items of the third and forth levels are taken from Erensal et al. model.

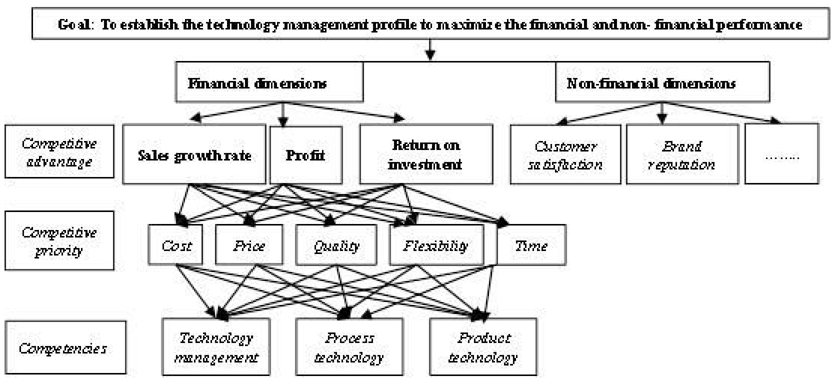

Fig. 1. The Hierarchy of the Interaction between the Performance-Related Elements [1].

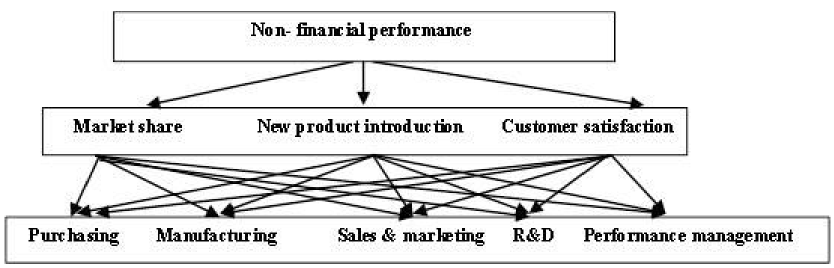

Fig. 2. Non-Financial Performance Evaluation AHP Model [7].

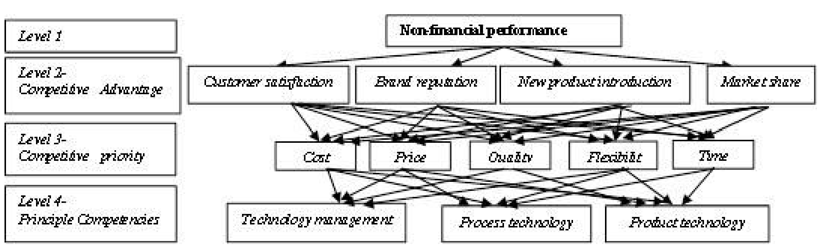

Fig. 3. The Hierarchy of Non-Financial Performance Measures.

2.1. Factors that influence the firm's technology selection

In a comprehensive study, Farokhi et al. [8] identified some factors that technology managers use to choose among alternative technologies. These factors include technological factors (technology flexibility, technology life cycle, attraction rate of technology components, effect of technology on the future life of the industry, product possession level for conducting the changes), technical factors (effect of technology on product quality, amount of increase in production efficiency, level of flexibility regarding product, process and machinery changes), financial factors (technology price, cost of repair and maintenance, the return on capital), trade factors (level of access to technology market, technology market elasticity), enterprise-related factors (availability of the resources, internal energy and knowledge, human infrastructure, enterprise infrastructure, government or legal infrastructure) and finally, environmental factors (dangerous effects at the end of technology life)[8].

2.2. Effect of technology selection on core (technological) competencies

Selection of the best technology helps the firms to produce more competitive services and products, develop more efficient processes and generally offer more effective solutions to customers. Firms should try to employ the best technology which is more suitable regarding customer and market needs, core competencies within the industry and their corporate plans [9]. Coombs studied the relationship between core competencies and the strategic management of R&D operations. He concluded that application of technology at innovation projects undergoes the complicated coordination processes to enhance the performance of products and processes; furthermore, the operational and marketing performance must be closely coordinated with each other. This coordination is in fact, an important prerequisite to nurture the firm's core competencies. Many of the technological capabilities relate to spillover enterprise units. For many firms, having some core competency is necessary for making strategic decisions like technology selection decision. Since some of the consequences of technology selection occur at long-run, firms' survival at long term depends heavily on their ability to exploit some core competencies.

In general, core competencies need three elements to be manipulated: skills, resources and processes. Proper technology can be one of the main resources needed to make a best use of core competencies [10]. In fact, technological competency is a key capability that empowers the firm to offer better value to customers [11]. So as can be seen, core competencies could be cited as a main competitive resource that will pave the way to acquire sustainable competitive advantage. As a whole, technology is the firm's strategic asset, and the firm's ability to effectively manage and exploit the technology is considered as an important competency at enterprise level. The technological competencies under investigation in this study include product technology, process technology and technology management, based on a model demonstrated by Erensal et al. [1]. Product technology is what customers buy and consume to satisfy their needs. Product technology is applied to develop the product and after-sales service and also to distribute products in market. Process technology refers to the tools and skills applied to produce products with minimal price. Furthermore, process technology includes technologies that apply to control quality, control inventory and to plan for the product to be produced [1].

Technology management is a process that includes planning, direction, control and coordination with the aim of developing and exploiting the technology capabilities and to meet the firm's strategic and operational objectives [2]. On the other hand, technology management includes: 1- planning to create technology capabilities, 2- identifying useful technologies and planning to apply the best technology, 3- deciding as to whether import technology or to develop it internally inside the firm, 4) creating intra-firm mechanisms to direct and coordinate for creating technology capabilities and for designing the control criteria [12].

3. Role of Competencies in Gaining Competitive Advantage

Technological competency refers to the firm's ability to exploit the best knowledge to produce and present its offers. In fact, technological competency is the most important factor leading to superiority in financial performance by making the best use of modern technologies [13]. Competitive advantage and core competencies are not necessarily the same, but they are closely related to each other. Torkeli and Tuominen [9] argue that the relationship between principal competency, competitive advantage and added value would be as follow:

Principal competency → competitive advantage ⟶ added value

Fig. 4. The Relationship between Principal Competency and Added Value [9].

This means that principal competency leads to competitive advantage, and also competitive advantage leads to added value [9]. According to Torkeli and Tuominen [9], firm's core competency is a basis to create competitive advantage in market. In the absence of core competencies, competitive advantage will not be sustainable and strategic objectives will not be attained [9]. Core competencies are distinct properties and skills that help firms to achieve the highest customer satisfaction level against competitors [14]. Because product life cycle has become short and competition has become intense in the new era of competition, much attention has been paid to create competitive advantage for firms [15]. According to Erensal et al. and Hafeez et al. [1, 7], Companies that find innovative ways to manage capabilities gain competitive advantages [16].competitive advantage is the firm's distinctive capability to dominate in the market. In this study, the customer satisfaction, brand reputation, new product introduction and market share are the main variables to be measured. Satisfaction is the feeling that customers have when they use a product or service [17]. Brand reputation is defined as the perception of quality associated with the name brand [18]. New product introduction is a measure of product and technology innovation. Market share is a factor used to measure market power of a firm [7]. New product development and market introduction are important for high technology new firms' successful performance [19].

4. Competitive Priority

In order to survive in global markets, managers need to have a clear understanding of competitive priorities. Production speed is considered as competitive priority in one firm, while producing the product with high quality and low price is competitive priority in other. In general, competitive priorities include factors such as low price, product quality, good delivery, flexibility and customer's service. Furthermore, after-sales service, technical support and extensive distribution can add the product value. Since different competitive priorities require different infrastructures and properties, therefore selecting and applying the suitable properties and infrastructures fitted to the firm's capabilities is of great importance [4].Competitive priorities are the attributes of a firm that attract customers [1]. According to the study conducted by Erensal et al., factors such as cost, price, quality, flexibility and time are included in the model of this study [1].

5. Fuzzy AHP

Despite of its wide range of applications, the conventional AHP approach may not fully reflect a style of human thinking. One reason is that decision makers usually feel more confident to give interval judgments rather than expressing their judgments in the form of single numeric values. As a result, fuzzy AHP and its extensions are developed to solve alternative selection and justification problems. Although fuzzy AHP requires tedious computations, it is capable of capturing a human's appraisal of ambiguity when complex multi-attribute decision making problems are considered. Chang's developed a fuzzy extent analysis for AHP, which has similar steps as that of Saaty's crisp AHP. However, his approach is relatively easier in computation than the other fuzzy AHP approaches.

In this paper, we make use of Chang's fuzzy extent analysis for AHP, applied Chang's fuzzy extent analysis in the selection of the best catering firm, facility layout and the best transportation company, respectively [1].

Let $O = \{o_1, o_2, \ldots, o_n\}$ be an object set, and $U = \{g_1, g_2, \ldots, g_m\}$ be a goal set. According to the Chang's extent analysis, each object is considered one by one, and for each object, the analysis is carried out for each of the possible goals, g_i. Therefore, m extent analysis values for each object are obtained and shown as follows:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \quad i = 1,2,\ldots,n$$

where $M_{g_i}^i \quad (j = 1,2,\ldots,m)$ are all triangular fuzzy numbers. The membership function of the triangular fuzzy number is denoted by $M(x)$. The definitions of the triangular fuzzy number and the fuzzy algebraic operations for fuzzy triangular numbers are given in Appendix A.1.

The steps of the Chang's extent analysis can be summarized as follows:

Step 1: The value of fuzzy synthetic extent with respect to the *i*th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^i \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^i\right]^{-1} \tag{1}$$

where × denotes the extended multiplication of two fuzzy numbers. In order to obtain $\sum_{j=1}^{m} M_{g_i}^j$, we perform the addition of m extent analysis values for a particular matrix such that,

$$\sum_{j=1}^{m} M_{g_i}^i = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{2}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^i\right]^{-1}$ we perform the fuzzy addition operation of $M_{g_i}^j \quad (i = 1,2,\ldots,m)$ values such that,

$$\sum_{i=1}^{n}\sum_{j=i}^{m} M_{g_i}^{i} = (\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i) \tag{3}$$

Then, the inverse of the vector is computed as,

$$[\sum_{i=1}^{n}\sum_{j=i}^{m} M_{g_i}^{i}]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{4}$$

where $\forall u_i, m_i, l_i > 0$

Finally, to obtain the S_j in Eq. (1), we perform the following multiplication:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{i} \times [\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{i}]^{-1}$$

$$= \left(\sum_{j=1}^{m} l_j \times \sum_{i=1}^{n} l_i, \sum_{j=1}^{m} m_j \times \sum_{i=1}^{n} m_i, \sum_{j=1}^{m} u_j \times \sum_{i=1}^{n} u_i\right) \tag{5}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = sup_{y \geq x}[\min(M_1(x), M_2(y))] \tag{6}$$

which can be equivalently expressed as,

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = M_2(d) = \begin{Bmatrix} 1\ if\ m_2 \geq m_1 \\ 0\ if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, Otherwise \end{Bmatrix} \tag{7}$$

Figure 5 illustrates $V(M_2 \geq M_1)$, for the case $m_2 < l_1 < u_2 < m_1$, where *d* is the abscissa value corresponding to the highest crossover point *D* between M_1 and M_2. To compare M_1 and M_2, we need both of the values $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

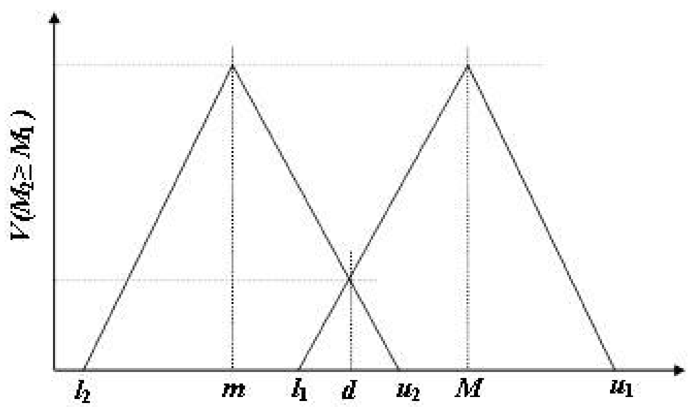

Fig. 5. The Degree of Possibility of $M_1 \geq M_2$.

Step 3: The degree of possibility for a convex fuzzy number to be greater than *k* convex fuzzy numbers $M_i (i = 1, 2, \ldots, k)$ is defined as

$V(M \geq M_1, M_2, \ldots, M_K)$ = min $V(M \geq M_i)$, *i*=1, 2,…, *k*.

Step4: Finally, $W = (minV(S_1 \geq S_K)minV(S_2 \geq S_K), \ldots, minV(S_n \geq S_k))^T$ is the weight vector for *k*=1,…, *n*

6. Aggregation of Group Decisions

Fuzzy pairwise comparisons can be combined by use of the following algorithm [20]:

$$l_{ij} = \min(l_{ijk}),\ m_{ij} = \left(\prod_{k=1}^{K} m_{ijk}\right)^{\frac{1}{k}},\ u_{ij} = \max(u_{ijk}) \tag{8}$$

where (l_{ijk}, m_{ijk}, u_{ijk}) is the fuzzy evaluation of sample members k (k = 1,2, … , K). However, min and max operations are not appropriate if the sample has a wide range of upper and lower bandwidths, in other words, if evaluations are inhomogeneous. We have to consider that if only one or few decision makers deliver extreme l_{ijk} and/or u_{ijk} the whole span of fuzzy numbers (l_{ij}, m_{ij}, u_{ij}) gets huge. Due to the required number of multiplication and addition operations, the aggregated fuzzy weights can even exceed the 0-1borders or become irrational [21], which is of course, unsatisfactory. Therefore, we decided to use the *geometric mean* also for l_{ij} and u_{ij} which delivers satisfying fuzzy group weightings. Geometric mean operations are commonly used within the application of the AHP for aggregating group decisions [22]:

$$l_{ij} = \left(\prod_{k=1}^{k} l_{ijk}\right)^{\frac{1}{k}},\ m_{ij} = \left(\prod_{k=1}^{k} m_{ijk}\right)^{\frac{1}{k}}, u_{ij} = \left(\prod_{k=1}^{k} u_{ijk}\right)^{\frac{1}{k}} \tag{9}$$

7. Research Methodology

The fuzzy analytic hierarchy process using Chang's extent analysis technique is used as the main statistical method of this study [23]. Firstly, the experts in Coil manufacturing industry in Iran were asked to compare the elements at each level of the model (competitive advantage, competitive priority, technological competencies) using the compound geometric mean method. Then, double comparison table, Table 1, was designed to compare the elements at each level. In the next step, the weights of each element at all levels were attained using fuzzy analytic hierarchy process. The model of the study is tested on a sample of 12 experts in 4 coil companies in Iran which have 90% of the market share in the coil industry. Coil producer firms which have been examined in this research include: 1- Iran Fanar- Lool firm in Damghan, 2- Omid-Fanar firm in Mashhad, 3- Khavar- manufacturing firm in Tehran, 4- Energy-Saz firm in Hamedan. The experts were asked to determine the importance of each one of the given items regarding technological competencies. The main tools used for gathering the data in this study were company records and questionnaire. In the questionnaire, experts were asked to state their ideas by comparing the conceptual model elements. The scales used to collect the expert's subjective answers are as follows:

Table 1. Verbal Concepts in Fuzzy Scale Spectrum.

Verbal scale	Triangle fuzzy numbers	Triangle fuzzy numbers reverse
Equal significant	(1, 1, 1)	(1, 1, 1)
A little more significant	(1, 3, 5)	(1/5,1/3, 1)
More significant	(3, 5, 7)	(1/7,1/5, 1/3)
Many more significant	(5, 7, 9)	(1/9, 1/7, 1/5)
Extremely significant	(7, 9, 11)	(1/11, 1/9, 1/7)

8. Research Findings

To compare the factors of competitive advantage (customer satisfaction, brand reputation, new product introduction, market share); the normalized weight of each element is shown in Table 2.

Table 2. Final Normalized Weights of Competitive Advantage Factors.

Customer	Satisfaction	Market share	Brand reputation	New product introduction
W	0.450	0.292	0.152	0.105

According to responses presented in Table 2, we can conclude that final sequence of competitive advantage importance would be as follows:

Competitive Advantage level-Customer satisfaction with obvious weight variance was proved to be the first priority at the second level, while market share, brand reputation, new product introduction were among the next priority levels. At the third level, Competitive Priorities level, we proposed four double comparison tables that are weighed and compared according to customer satisfaction, brand reputation, new product introduction and market share, respectively. The results attained from spillover weights of each one of factors at the industry are presented in Tables 3 to 6.

Table 3. Final Weight of Competitive Priorities Regarding Customer Satisfaction Criteria.

	Quality	Time	Flexibility	Price	Cost
W	0.518	0.164	0.135	0.116	0.067

Table 4. Final Weight of Competitive Priorities Regarding Brand Reputation Criteria.

Criteria	Quality	Time	Flexibility	Price	Cost
W	0.486	0.271	0.220	0.019	0.003

Table 5. Final Weight of Competitive Priorities Regarding New Product Introduction Criteria.

Criteria	Quality	Time	Flexibility	Price	Cost
W	0.487	0.224	0.144	0.081	0.064

Table 6. Final Weight of Competitive Priorities Regarding Market Share Criteria.

Criteria	Quality	Time	Flexibility	Price	Cost
W	0.434	0.277	0.144	0.093	0.052

According to Table 3, comparing 5 competitive priority measures (Level 3) regarding customer satisfaction, the results show that quality, time, flexibility, price and cost are in the hierarchy of importance respectively. By comparing these measures according to brand reputation, as presented in Table 4, we can conclude that quality, time, flexibility, price and cost are in the order of importance respectively. As far as new product introduction is involved, results of Table 5 show that quality, time, price, flexibility and cost are in importance hierarchy, respectively. Comparing these measures regarding market share, as stated in Table 6, results show that the sequence of importance are quality, time, flexibility, price and cost, respectively.

For technological competency level, we have designed a double comparison table using factors which stated before. The results attained from spillover corporate weights of each factor at coil manufacturing industry are presented in Tables 7 to 11.

Table 7. Final Weight of Technological Competencies Regarding Cost Criteria.

	Process Technology	Technology Management	Product Technology
W	0.436	0.423	0.141

Table 8. Final Weight of Technological Competencies Regarding Price Criteria.

	Process Technology	Technology Management	Product Technology
W	0.512	0.274	0.214

Table 9. Final Weight of Technological Competencies Regarding Quality Criteria.

	Process Technology	Technology Management	Product Technology
W	0.592	0.396	0.012

Table 10. Final Weight of Technological Competencies Regarding Flexibility Criteria.

	Process Technology	Technology Management	Product Technology
W	0.465	0.320	0.215

Table 11. Final Weight of Technological Competencies with Regarding Time Criteria.

	Process Technology	Technology Management	Product Technology
Time	0.422	0.323	0.255

By comparing 3 elements related to technological competencies regarding cost, as shown in Table 7, the results indicate that technology management is the first priority while process technology and product technology are in the next priority level respectively. Comparing 3 elements related to technological competencies regarding price, the result of Table 8 shows that technology management is the first priority, while process technology and product technology are among the next priorities. Comparison of the 3 elements related to technological competencies in terms of quality, Table 9 states that process technology is in the first priority level while product technology and technology management are in the next priority level. The result of comparing 3 elements related to technological competencies regarding flexibility as the core index, as specified in Table 10 shows that process technology is the first priority while technology management and product technology are in the next level. Finally, comparing the 3 elements related to technological competencies regarding time, as presented in Table 11, process technology is in the first priority level but technology management and product technology are in the next priority level.

The element's weights at three levels were combined together in Table 12 and final weights of technological competencies were attained. As indicated in table below, from coil manufacturing industry managers' point of view, final sequence of technological competency importance with the aim of maximizing the non-financial performance is as follows:

Process technology with an obvious weight variance is at the first priority level, while product technology is at the second level and finally technology management in the third priority level.

Table 12. Combining the Weights of Three Levels and Computing the Final Weight of Technological Competencies with Objective of Maximizing the Non-Financial Performance.

	Customer Satisfaction (0.450)				
	Cost	**Price**	**Quality**	**Flexibility**	**Time**
	0.067	0.116	0.518	0.135	0.164
Technology Management	0.436	0.512	0.012	0.320	0.323
Process Technology	0.423	0.274	0.592	0.465	0.422
Product Technology	0.141	0.214	0.396	0.215	0.255

	Brand Reputation (0.152)				
	Cost	**Price**	**Quality**	**Flexibility**	**Time**
	0.003	0.019	0.486	0.220	0.271
Technology Management	0.436	0.512	0.012	0.320	0.323
Process Technology	0.423	0.274	0.592	0.465	0.422
Product Technology	0.141	0.214	0.396	0.215	0.255

	New Product introduction (0.105)				
	Cost	**Price**	**Quality**	**Flexibility**	**Time**
	0.064	0.144	0.487	0.081	0.224
Technology Management	0.436	0.512	0.012	0.320	0.323
Process Technology	0.423	0.274	0.592	0.465	0.422
Product Technology	0.141	0.214	0.396	0.215	0.255

	Market share (0.292)					
	Cost	**Price**	**Quality**	**Flexibility**	**Time**	
	0.052	0.093	0.434	0.144	0.277	Avg.
Technology Management	0.436	0.512	0.012	0.320	0.323	0.196
Process Technology	0.423	0.274	0.592	0.465	0.422	0.496
Product Technology	0.141	0.214	0.396	0.215	0.255	0.308

9. Conclusions

This study explores the relationship between competitive advantage (customer satisfaction, brand reputation, new product introduction and market share), competitive priorities (cost, price, quality, flexibility and time) and technological competencies (product technology, process technology, technology management) with the aim of maximizing the firm's nonfinancial performance. Technological competencies were compared using fuzzy AHP technique based on the data collected from 12 experienced managers of various firms at coil manufacturing industry in Iran. Results show that in the Iran's coil manufacturing industry, the process technology is the most important subcategory of technology employed, while product technology is at the next lower level of importance. In fact, to have a better non-financial performance at coil manufacturing industry in Iran, firms need to enhance their understandings of the process technology and also to apply the most recent knowledge developed in this area. Successful implementation of the process technology hinges to some degree, on the firm's clear and correct understanding on present and, to some extent, on future market needs and also on investing in the appropriate IT infrastructure to support these requirements. The results of the comparison of factors affecting non-financial performance against factors affecting financial performance [1, 24] indicate that in both of the cases, customer satisfaction is the first priority [7]. Although, some difference is observed in this regards: For instance in the latter studies, it is claimed that new product introduction and market share were found to be at the second and third level of priority respectively. The results of this study on the other hand indicates that market share is at the second level of priority, while the brand reputation is at the third priority level and the new product introduction is at the forth priority level (shown in Table 13).

Table 13. Comparison of Factors.

Level of Priority	In Ernesal et al. [1] and Vali-pour Khatir [24]	In Recent Study
	Financial performance	Non-financial performance
Level of Priority	In Hafeez et al. [7]	In Recent Study
First Priority Level	Customer satisfaction	Customer satisfaction
Second Priority Level	New Product Introduction	Market Share
Third Priority Level	Market Share	Brand Reputation
Fourth Priority Level	-	New Product Introduction

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Appendix A

A.1. Definition of the Triangular Fuzzy Number and the Operational Laws of Triangular Fuzzy Numbers

The membership function $M(x): R \rightarrow [0,1]$ of the triangular fuzzy number $M = (l, m, u)$ defined on R is equal to

$$M(x) = \begin{Bmatrix} \frac{x-1}{m-l}, & x \in [l,m] \\ \frac{x-u}{m-u}, & x \in [m,u] \\ 0 & \text{otherwise} \end{Bmatrix}$$

where $l \leq m \leq u$ and, l and u are respectively lower and bound values of the support of M[1].

According to Zadeh's extension principle given two triangular fuzzy numbers $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$

- The extended addition is defined as $M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$.
- The extended multiplication is defined as $M_1 \times M_2 \approx (l_1 l_2, m_1 m_2, u_1 u_2)$.
- The inverse of triangular fuzzy number $M_1 = (l_1, m_1, u_1)$is defined as
  $M_1^{-1} \approx \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$.

A.2. Questionnaire

The questions in our questionnaire are prepared according to the FAHP model presented in Section 2. A group of 12 managers from various firms at coil manufacturing industry in Iran are the sample of the study. A sample of questions from the questionnaire is given below:

If an attribute on the left is more important than the one on the right, put cross mark ‘‘X’’ to the left of the ‘‘Equal Importance’’ column, under the importance level (column) you prefer. On the other hand, if an attribute on the left is less important than the one on the right, put cross mark ‘‘X’’ to the right of the ‘‘Equal Importance’’ column, under the importance level (column) you prefer.

Q1. How important is the customer satisfaction when it is compared to brand reputation?

Q2. How important is the customer satisfaction when it is compared to new product introduction?

Q3. How important is the customer satisfaction when it is compared to market share?

Q4. How important is the brand reputation when it is compared to new product introduction?

Q5. How important is the brand reputation when it is compared to market share?

Q6. How important is the new product introduction when it is compared to market share?

The answers related for these sample questions are presented in Table A-1.

Table A-1. Answers to Some of the Sample Questions from the Questionnaire.

With respect to: the non-financial performance		Importance (or preference) of one sub-attribute over another								
Questions	**Alternatives**	**Demonstrated importance**	**Very strong importance**	**Strong Importance**	**Moderate Importance**	**Moderate Unimportance**	**Strong Unimportance**	**Very strong unimportance**	**Demonstrated unimportance**	**Alternatives**
Q1	**Customer satisfaction**						√			**Brand reputation**
Q2	**Customer satisfaction**		√							**New product introduction**
Q3	**Customer satisfaction**							√		**Market share**
Q4	**Brand reputation**						√			**New product introduction**
Q5	**Brand reputation**								√	**Market share**
Q6	**New product introduction**								√	**Market share**

A.3. Geometric Mean

We unified the elites’ opinions. For combining the decision–makers (elites) fuzzy weights, geometry mean is used.

$\overline{w_i} = \left(\prod_{k=1}^{k} w_i^k\right)^{\frac{1}{k}}, \forall k = 1,2,..,k > 0$, or $GM = \sqrt[n]{a_1 . a_2 \cdots a_n}$

The elites' opinions about comparing of competitive advantage factors have been shown in Table A-2.

Table A-2. The Elites' Opinions about Comparing of Competitive Advantage Factors.

Expert 1

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1, 3, 5)	(1, 1, 1)	(1/7, 1/5, 1/3)
Brand reputation	(1/5, 1/3, 1)	(1, 1, 1)	(1, 1, 1)	(1/5, 1/3, 1)
New product introduction	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
Market share	(3, 5, 7)	(1, 3, 5)	(1, 1, 1)	(1, 1, 1)

Expert 2

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1/5, 1/3, 1)	(1/5, 1/3, 1)	(1, 1, 1)
Brand reputation	(1, 3, 5)	(1, 1, 1)	(1/5, 1/3, 1)	(1/9, 1/7, 1/5)
New product introduction	(1, 3, 5)	(1, 3, 5)	(1, 1, 1)	(1/9, 1/7, 1/5)
Market share	(1, 1, 1)	(5, 7, 9)	(5, 7, 9)	(1, 1, 1)

Expert 3

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1, 1, 1)	(1/5, 1/3, 1)	(1/5, 1/3, 1)
Brand reputation	(1, 1, 1)	(1, 1, 1)	(1/5, 1/3, 1)	(1, 1, 1)
New product introduction	(1, 3, 5)	(1, 3, 5)	(1, 1, 1)	(1/5, 1/3, 1)
Market share	(1, 3, 5)	(1, 1, 1)	(1, 3, 5)	(1, 1, 1)

Expert 4

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	(1/9, 1/7, 1/5)
Brand reputation	(1/5, 1/3, 1)	(1, 1, 1)	(1, 3, 5)	(1/9, 1/7, 1/5)
New product introduction	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1, 1, 1)	(1/11, 1/9, 1/7)
Market share	(5, 7, 9)	(5, 7, 9)	(7,9,11)	(1, 1, 1)

Expert 5

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(5, 7, 9)	(3, 5, 7)	(1, 1, 1)
Brand reputation	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/11, 1/9, 1/7)	(5, 7, 9)
New product introduction	(1/7, 1/5, 1/3)	(7,9,11)	(1, 1, 1)	(1/5, 1/3, 1)
Market share	(1, 1, 1)	(1/9, 1/7, 1/5)	(1,3,5)	(1, 1, 1)

Expert 6

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1, 1, 1)	(3, 5, 7)	(1, 1, 1)
Brand reputation	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1/5, 1/3, 1)
New product introduction	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
Market share	(1, 1, 1)	(1, 3, 5)	(1, 1, 1)	(1, 1, 1)

Expert 7

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(3, 5, 7)	(7,9,11)	(3, 5, 7)
Brand reputation	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 1, 1)	(3, 5, 7)
New product introduction	(1/11, 1/9, 1/7)	(1,1, 1)	(1, 1, 1)	(1, 3, 5)
Market share	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1, 1, 1)

Expert 8

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(1,3, 5)	(1,3, 5)	(3, 5, 7)
Brand reputation	(1/5, 1/3, 1)	(1, 1, 1)	(1/5, 1/3, 1)	(1/5, 1/3, 1)
New product introduction	(1/5, 1/3, 1)	(1, 3, 5)	(1, 1, 1)	(1, 1, 1)
Market share	(1/7, 1/5, 1/3)	(1, 3, 5)	(1, 1, 1)	(1, 1, 1)

Expert 9

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(3, 5, 7)	(7,9,11)	(1,3, 5)
Brand reputation	(1/7, 1/5, 1/3)	(1, 1, 1)	(1,3, 5)	(1,3, 5)
New product introduction	(1/11, 1/9, 1/7)	(1/5, 1/3, 1)	(1, 1, 1)	(1/9, 1/7,1/ 5)
Market share	(1/5, 1/3, 1)	(1/5, 1/3, 1)	(5, 7, 9)	(1, 1, 1)

Expert 10

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(3, 5, 7)	(1,3, 5)	(1,3, 5)
Brand reputation	(1/7, 1/5, 1/3)	(1, 1, 1)	(1/5, 1/3, 1)	(1/5, 1/3, 1)
New product introduction	(1/5, 1/3, 1)	(1, 3, 5)	(1, 1, 1)	(1, 3, 5)
Market share	(1/5, 1/3, 1)	(1, 3, 5)	(1/5, 1/3, 1)	(1, 1, 1)

Expert 11

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(5, 7, 9)	(5, 7, 9)	(5, 7, 9)
Brand reputation	(1/9, 1/7, 1/5)	(1, 1, 1)	(3, 5, 7)	(1, 1, 1)
New product introduction	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1/7, 1/5, 1/3)
Market share	(1/9, 1/7, 1/5)	(1, 1, 1)	(3, 5, 7)	(1, 1, 1)

Expert 12

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1, 1, 1)	(5, 7,9)	(7,9,11)	(3, 5,7)
Brand reputation	(1/9, 1/7, 1/5)	(1, 1, 1)	(5, 7,9)	(3, 5,7)
New product introduction	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/7,1/ 5,1/3)
Market share	(1/7,1/ 5,1/3)	(1/7,1/ 5,1/3)	(3, 5,7)	(1, 1, 1)

After unifying the elites' opinions, by using the geometry mean, the following table (Table A-3) has attained.

Table A-3. Results of Unifying the Elites' Opinions using the Geometry Mean.

	Customer satisfaction	Brand reputation	New product introduction	Market share
Customer satisfaction	(1.000, 1.000, 1.000)	(1.721, 2.921, 4.213)	(1.872, 3.046, 4.652)	(0.932, 1.433, 2.038)
Brand reputation	(0.237, 0.342, 0.581)	(1.000, 1.000, 1.000)	(0.600, 0.932, 1.570)	(0.557, 0.845, 1.453)
New product introduction	(0.215, 0.328, 0.534)	(0.637, 1.072, 1.666)	(1.000, 1.000, 1.000)	(0.314, 0.460, 0.708)
Market share	(0.491, 0.698, 1.073)	(0.688, 1.184, 1.796)	(1.412, 2.172, 3.185)	(1.000, 1.000, 1.000)

A.4. Fuzzy AHP computation

For the first step of the analysis, the pair-wise comparison matrix for the main attributes is built (see Table A-4).

Table A-4. Results of Pair-wise Comparison Matrix for the Main Attributes.

	Customer satisfaction	Brand reputation	New product introduction	Market share	$\sum_{i=1}^{m}\sum_{j=1}^{n} M_{ij}$
Customer satisfaction	(1.000, 1.000, 1.000)	(1.721, 2.921, 4.213)	(1.872, 3.046, 4.652)	(0.932, 1.433, 2.038)	(5.525, 8.400, 11.903)
Brand reputation	(0.237, 0.342, 0.581)	(1.000, 1.000, 1.000)	(0.600, 0.932, 1.570)	(0.557, 0.845, 1.453)	(2.394, 3.120, 4.604)
New product introduction	(0.215, 0.328, 0.534)	(0.637, 1.072, 1.666)	(1.000, 1.000, 1.000)	(0.314, 0.460, 0.708)	(2.166, 2.861, 3.909)
Market share	(0.491, 0.698, 1.073)	(0.688, 1.184, 1.796)	(1.412, 2.172, 3.185)	(1.000, 1.000, 1.000)	(3.591, 5.053,7.054)
	(1.943,2.368,3.188)	(4.046,6.177,8.675)	(4.884,7.150,10.408)	(2.803,3.738,5.199)	(13.676,19.434,27.470)

For the second level, the values of fuzzy synthetic extents with respect to the main attributes are calculated as below

$$\sum_{i=1}^{m}\sum_{j=1}^{n}M_{ij}=\left(\sum_{i}^{n}l_i,\sum_{i}^{n}m_i,\sum_{i}^{n}u_i\right)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{gi}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_i},\frac{1}{\sum_{i=1}^{n}m_i},\frac{1}{\sum_{i=1}^{n}l_i}\right)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n}M_{ij}=(13.676,\ 19.434,\ 27.470)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{gi}^{j}\right]^{-1}=(0.036,\ 0.051,\ 0.073)$$

$$S_k=\sum_{j=1}^{n}M_{kj}\otimes\left[\sum_{i=1}^{m}\sum_{j=1}^{n}M_{ij}\right]^{-1}$$

$S_{Customer\ Satisfaction}=(0.036,0.051,0.073)=(0.199,0.428,0.869))\times 5.525,8.400,11.903)$

$S_{Reputation\ Brand}=(2.394,3.120,4.604)\times(0.036,0.051,0.073)=(0.086,0.159,0.336)$

$S_{New\ Product\ Introduction}=(2.166,2.861,3.909)\times(0.036,0.051,0.073)=(0.078,0.146,0.285)$

$S_{Market\ Share}=(3.591,\ 5.053,\ 7.074)\times(0.036,\ 0.051,\ 0.073)=(0.129,\ 0.258,\ 0.515)$

The degrees of possibility are calculated as below:

$V(S_{Customer\ Satisfaction}\geq S_{Reputation\ brand})=1.000$
$V(S_{Customer\ Satisfaction}\geq S_{New\ Product\ Introduction})=1.000$
$V(S_{Customer\ Satisfaction}\geq S_{Market\ Share})=1.000$

$V(S_{Reputation\ brand}\geq S_{Customer\ Satisfaction})=0.338$
$V(S_{Reputation\ brand}\geq S_{New\ Product\ Introduction})=1.000$
$V(S_{Reputation\ brand}\geq S_{Market\ Share})=0.677$

$V(S_{New\ Product\ Introduction}\geq S_{Customer\ Satisfaction})=0.234$
$V(S_{New\ Product\ Introduction}\geq S_{Reputation\ brand})=0.938$
$V(S_{New\ Product\ Introduction}\geq S_{Market\ Share})=0.583$

$V(S_{Market\ Share}\geq S_{Customer\ Satisfaction})=0.649$
$V(S_{Market\ Share}\geq S_{Reputation\ brand})=1.000$
$V(S_{Market\ Share}\geq S_{New\ Product\ Introduction})=1.000$

For each pair-wise comparison, the minimum of the degrees of possibility is found as below:

Min $V(S_{Customer\ Satisfaction}\geq S_i)=1.000$
Min $V(S_{Reputation\ brand}\geq S_i)=0.338$

Min $V(S_{New\ Product\ Introduction} \geq S_i) = 0.234$
Min $V(S_{Market\ Share} \geq S_i) = 0.649$

These values yield the following weights vector:

$W = (1.000, 0.338, 0.234, 0.649)^T$

Via normalization, the importance weights of the main attributes are calculated as follows:

$W = (0.450, 0.152, 0.105, 0.292)$

Also for computing the final weight of Tables A-2 through A-4, the same above steps are acted.