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The Portfolio Examination and Selection of Raw Material Suppliers, Based on Lean or Agile

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Abstract *The aim of this study was to determine the importance of agility and lean criteria in selecting the supplier of ceramic tiles' raw materials for paints and glazes in active companies of Najaf Abad city, as well as the ranking the suppliers. In this study, first, the related literature in the field of supplier's selection based on agility and lean was reviewed. Then, a conceptual model of agility and lean criteria and sub-criteria was presented. For data analysis experts' ideas were used. In addition, to analyze the data, the weight of each criteria and sub criteria of agility and leanness was gained through the method of analysis of hierarchical process (AHP) and to rank the suppliers of each company, the TOPSIS method was applied. According to the obtained data, the most important sub criteria were warranty and replacement policy, capability of R and D and innovation, and product durability, the other criteria gained the other places in ranking. Focusing on both agility and leanness criteria of suppliers reduce costs and enhance product quality and increase the speed and flexibility in changing needs of the market, which is an important issue in today's constantly changing and growing markets. In this study, we aimed to combine the agility and leanness criteria in selecting the suppliers in order to reach higher speed in responding to the market's changes, meeting the costumers' needs and higher quality of production in the local and international markets. Moreover, it was also intended to decrease the cost of manufacturing operations and reduce delays in the delivery of goods to the consumer.*

Key words Agile manufacturing, lean manufacturing, suppliers, TOPSIS, AHP

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1. Introduction

In the past decade, managers found out the importance of supply chain's role in valuing their firms. The fast changes in world markets have dramatically changed the managers' view towards to their surroundings. Customer's demands, short cycle of product life, increased competition and globalization are among those factors that has changed the business world. Customers constantly ask more values base on the location desirability, time, form, state and asset of organization and organizations must respond to these changes to remain in the field of competition (Hoseinzade and Jafarian, 2010). Environment pressures causes supply chain and its proper management, turns to an important factor for successful presence in competitive markets and this factor is competitive advantage for firms (Choi *et al*., 2007).

Supply chain management looks for reducing risk in supply chain, in order to follow goals like improving the level of customer's satisfaction, optimizing and managing inventory and higher profit (Esmithchi *et al*., 2003). One of the areas that managers pay more attention to is source discovering and purchase management.

In the past decade, purchase management has been a main challenge for many firms and access to the level of global competition become a basic requirement (Karpak *et al.,* 2001) with no doubt, the most important and most sensitive phase in a purchase process of any organization is assessing and selecting suppliers. Simple search for suppliers that offer the lowest price isn't an efficient way, and different criteria must be applied to select suppliers (Leung, 2007). Over the past years, a bunch of methods for supplier

assessment and selection have been offered, however specialists believe that in practice there is no optimized and unique method for assessing suppliers (Bello,2003). Therefore, firms use different methods in this regard based on their requirements. However, it makes it difficult to find the best assessment method and selection of suppliers (Keccin *et al*., 2010). Different methods have been employed in previous studies to choose the best supplier and the can be classified based on production methods adopted by suppliers. Most of the previous researches have focused on lean performance of supplier and only few of them have focused on the agile performance of supplier. However no one has considered suppliers with these characteristic simultaneously, and the advantage of considering these two groups of suppliers concurrently is the low cost and high quality, along with the capability of performing fast and flexible when required (Kadkhodazadeh and Morovati, 2012). After final selection phase, firms must have different behaviors for relationship management with these two types of suppliers (agile and lean.)

According to the cases explained above, focusing on both agile and lean criteria of suppliers for choosing them cause reduction in costs and increase in the quality of production and also increasing the speed and flexibility for changing needs of market, that these are important issues in growing and constantly changing markets. Regarding what has been mentioned, it is tried to achieve these goals by combining the agile and lean criteria, in supplier selection of glaze's tiles and ceramic in target factory. Our goals are responding to market changes quickly and, responding to daily changing needs of consumer, producing high quality products, reducing the costs of production, and reducing the delivery time. The goals of this research could be explained as follows:

1) Determining the importance of lean and agility criteria in supplier's selection.

2) Ranking suppliers based on agility and lean criteria.

2. Description and expression of research issue

Nowadays supply chain environment is more dynamic and unpredictable than the past. The nature of supply chain characterized by parameters like product demand, product difference, and life cycle of product and other factors (Agarwal *et al*., 2006).

Since these factors are changing constantly and are not fixing, companies should check out their supplying strategy wisely to cover the environmental turbulence. In addition, it should be noted by companies that their strategy selection is effective in their competition in the market.

Supply chain contains all activities related the process of products and information from raw material suppliers to the delivery of products to customer and it focus on improving service delivery to customers, profitability and performance of organization (Vinodh *et al*., 2011).

Variations in customers' demand, recent development in information (data) systems, global competition, and increase in government rules and regulations force organization to focus on supply chain (Kilincci and Onal, 2011). The goal can be achieved by increasing efficiency and quick response to the market needs. Most firms follow intellectual paradigm of lean production in order to improve their efficiency of business processes (Mason-Jones *et al*., 2000).

The lean production is Toyota production system founded by Tai Chi Ohno. The philosophy of Lean production is removing any non-value added activities. Principles of lean production contains eliminating the waste products, zero defects, multi-functional teams, reducing organizational layers, team leadership, continues improvement and pull system (Faraji, 2013).

However, responding to the market needs is not only speed, but also the high level of maneuver's capability which is nowadays known as agility statement. Agile product's aims are customer enrichment; manufacturing products according to her/his need, leverage the information and people, controlling changes and lack of reliability and increase in competitiveness by cooperation. Agile production paradigm provides a technical framework and necessary strategy and allows firms to have versatile and flexible behavior based on the appearance of new patterns of demand in competitive market (Faraji, 2013).

One of the leading sections in key activities of firms is the purchase section. Lack of clarity on performance indicators purchase makes the purchasing decision very important (De Boer *et al*., 2001). One of the important issues in the purchase section is selection of suppliers. Undeniably, Selecting Suppliers is the corner stone of a successful purchase and supply management in order to maintain and improve the competitive base is concerned (Wang, 2010).

Considering the present conditions like fast pace of changes and market volatility in terms of price and materials quality, reduction in product life and global market, have made firms to identify and harmonize all parts cooperating together to provide customers' demands directly and indirectly by creation management system. Selecting Suppliers is an important decision in production and logistics management that during it suppliers are evaluated. In this study, first, the main criteria in choosing the suppliers of supply chain were studied from lean and agile perspective and then the literature related to choosing suppliers and different approaches applied for selection was reviewed. In addition, AHP and TOPSIS methods were used for analysis. This research implemented in terms of selecting suppliers of raw materials as color and glaze of ceramic and tiles in five companies. Since the lean and agile perspective has not been combined implementing this study in five companies synchronously considers being new and useful. We hope after determining the importance of each criteria and rating and determining the best suppliers for each company, the results of this research might be useful for managers of these companies.

3. Literature review

There have been a number of studies in which lean or agile approach was applied to select suppliers. In this study, the related works for selecting suppliers were categorized based on the agile or lean approach and it was found that most studies have just focused on one of the agile or lean approaches not both. It seems that fewer studies focus on agile and lean approach synchronously.

3.1. Related studies applying lean approach for selecting suppliers

Cebeci *et al*. (2003) stated that the supplier selection criteria, typically categorized according to supply, product performance, benchmark and service performance and cost criteria. They investigated customer satisfaction in the Turkish catering companies using the AHP fuzzy method. Bevilacqua *et al*. (2006), in order to select their suppliers used Fuzzy separation in the HOQ approach (for example QFD). The research was conducted in medium to large industries which were active in the field of clutch connections. The Six main criteria of the study were Product compatibility, cost, punctuality in delivering, the efficiency of corrective actions, availability and customer support, and transportation planning. Razmi and Maghool (2011) presented a fuzzy bi-objective model for multiple item, multiple courses, supplier selection and purchase under limited capacity and funding. Different payment methods presented daily by suppliers were researched. In the proposed model two goals of reducing the purchase cost and increasing the total amount of purchase were considered. The criteria used in this study were cost, quality, on-time delivery, after-sales services. They applied Chebyshev method to analyze the data. Setak *et al*. (2012),reviewed supplier selection and applied the allocation method based on an extensive research in the literature and hold that price, quality and delivery were important criteria .The results of the study indicated that the recent studies applied more mathematics (quantitative) model for suppliers' selection than qualitative ones. Sadeghian and Masnadjam (2015) implemented a research for selecting suppliers in automobile parts manufacturing in Hamadan. They clustered the required items and applied TOPSIS method according to three criteria of quality, price and delivery time to rank the suppliers of the company. Selcuk and Batuhan (2015), in a study in a Turkish Gear Motor Co., used fuzzy AHP method to determine the significance of criteria then suppliers were ranked by using Multi Integrated Linear Program (MILP). The applied criteria were price, quality, delivery, and after-sale services.

3.2. Related studies applying agile approach for selecting suppliers

Luo *et al*. (2009), conducted a study in the manufacture of electronic devices in China and in this study, three criteria of technological and managerial capabilities, financial strength and quality of company resources were chosen in the format of 31 sub criteria to analyze the data. The study indicated that company's decision makers can choose their supplier according to the local needs and market demands. Wu and Barnes (2010), researched industry and electronics equipment manufacturer in China, and applied optimization theory and Dempster-Shafer for formulating criteria for supplier selection decisions in the agile supply chain. Criteria examined in this study were financial strength, human resource management, marketing capabilities, cooperative management, organizational and industrial competence, logistics and production management, and asset management. Farokh *et al*. (2011), applied multi-criteria decision-

making methods for ranking and selecting the competent manufacturer to improve agility in Bahman Motors. The criteria were strategies, technologies, systems, and people. The study of Chang *et al*. (2011) used the Fuzzy DEMATEL method for selecting efficient and effective criteria. The used criteria were strategic relationships, expertise, capability in agreements, and mutual confidence. Their research proved that the stable delivery of goods was very effective and strongly linked with other criteria. Ertugrul *et al*. (2014) ran a study in a non-governmental hospital in Turkey. He named the studied criteria Home Quality which contained customer needs, important customer needs, technical attributes, internal dependence between technical attributes, competitive Assessment matrix, the overall priorities of technical attributes and additional goals. As a result of this study, the number of comparative values for FWA (Fuzzy Weighted Average) against MCDM (multi-criteria decision making) was obtained.

4. Supplier selection methods

There have been a number of methods for selecting and assessing the suppliers. However, experts believe that there has not been found no practical efficient method for assessing suppliers (Bello, 2003).Therefore, companies have applied different methods based on their requirements. That is why selecting the best method of assessing and selecting suppliers is difficult (Keccin *et al*., 2010).

Since assessing and selecting suppliers is a decision making issue, a number of studies have analyzed it. Naraziman (1983) applied AHP in selecting suppliers. Also Barbara Sernler and Bezgag (1997), Ghodsipour and O'Brien (2009), used a combination of AHP and linear programming. Karamn *et al*. (2003), Huk and Cunnan (2006), used fuzzy AHP method in this area. In the past few years, the data envelopment analysis (DEA) has been proposed as an important means of measuring performance. DEA is a non-parametric method which does not need the estimation of production function (Amiri and Jahani, 2011). In this study, the methods used in previous studies were reviewed from two perspectives:

1. The single methods.
2. The integrated methods (Hu *et al.,* 2010).

4.1. Single methods

Single methods use one method to select the suppliers. DEA technique, mathematical programming, AHP, fuzzy theory and genetic algorithm are among the widely used methods.

Razmi and Maghool (2011) presented a fuzzy bi-objective model for multiple titles, multiple courses, supplier selection and purchase problem under budget limitation and capacity constraint. They applied Chebyshev method for analyzing the data. Kadkhodazadeh or Moravati (2011), to select suppliers in a food company applied Fuzzy Inference System with regard to the criteria of cost, quality, service, relations and organizational structure of suppliers. The system input is the score of each supplier in any criteria obtained with ANP method and its output is final score of each supplier. Moghadam (2015), used a "fuzzy multi-objective mathematical model" to determine and classify the best suppliers and to find the new optimal number and under construction and the final product in a logistics network playoffs. To analyze the data, AHP approach was applied. Wei and Orji (2015) analyzed the data with MCDM approach in a Chinese gearbox and gear manufacturing company. Selcuk and Batuhan (2015) applied the AHP fuzzy method to determine the significance of criteria and then by using Multi Integrated Linear Program (MILP) ranked the suppliers.

4.2. Integrated methods

Integrated methods are those that combine two or more methods. Most techniques used in such research, were made by combining AHP, DEA, fuzzy combination methods, DEA and multi-objective planning, multi-criteria decision-making methods (MCDM), genetic algorithms combination and neural networks.

Hadadian *et al.* (2009), conducted a study titled Multi - Criteria Selection of suppliers using AHP fuzzy. They used a fuzzy ANP model for comparing suppliers to choose the best supplier of plastic parts in Saina industry (household appliance manufacturer). Sadeghpour *et al*. (2011) assessed and selected suppliers of an automotive parts manufacturing company by using an integration model of fuzzy hierarchical analysis programming (FUZZY AHP) and fuzzy mathematical programming. The used model consisted of two stages:

in the first stage using fuzzy hierarchical analysis, the marginal utility suppliers were calculated by taking 13 factors into account. Then in the second stage, optimal buying portfolio of suppliers was achieved using fuzzy linear programming model. Tadic *et al.* (2014) offered new hybrid multi-criteria decision-making methods to solve complex problems that integrated DEMATEL, ANP, VIKOR procedures in the composition of the fuzzy concept. This model presented the integration of VIKOR, ANP, DEMATEL methods in the fuzzy sense for the first time. Sahebi *et al.* (2015) ran a study titled Employing an Integrated Approach of QFD and Fuzzy TOPSIS in Supplier Selection. They combined fuzzy logic and house of quality, and considered qualitative criteria in supplier selection process of Upright grille in the Saze Gostar Saipa Company and rated the company's suppliers.

According to the above mentioned researches, integrated methods for supplier selection has an increasing use and emphasizes the importance and accuracy of these methods in the evaluation and selection of suppliers. Therefore, in this study, AHP method is used to calculate the weight of criteria, and TOPSIS method is used for selection and ranking the suppliers.

5. Supplier selection criteria

So far many studies have been done about supplier selection and different criteria and methods have been provided. The number of factor that can be used to select a supplier is not just the magnitude but also concepts like strategy, mission statement, kind of product, market condition and etc. Since 1960 supplier selection criteria and supplier performance has been the base of many researchers.

In many recent studies, quality, on time delivery, price, production capacity, management, technology and flexibility has been selected as the criteria. However, it should be noted that the importance of factors regarding supplier selection can change based on purchase type and product kind (Kadkhodazadeh and Morovati, 2013). Criteria selection usually is done in one of the following class:

1. Supplier criteria.
2. Product performance criteria.
3. Service performance criteria.
4. Cost criteria.

Criteria must be commensurate with the planned levels of activities. Moreover, it is possible that company at the first step created criteria and standards that are not applicable to some suppliers or products and special service (Kahraman *et. al*, 2003) Generally, to select a supplier it is not just the price that should be considered, there are a wide range of factors that we could consider them for long term and strategic cooperation according to the supplier capability (Kadkhodazadeh and Morovati, 2013).

6. Criteria classification of supplier selection

In this part of research, a classification of criteria for supplier selection is provided based on agility and lean.

6.1. Agility perspective

In today's competitive business environment to stabilize and improve the firm's situation in market, firms should be too agile and sensitive to the changes in demand, policy and etc. Agile supply chain needs high flexibility to redesign the respond to surrounding changes (Lu *et al*., 2009). Agile production is defined as ability to succeed in commercial competition environment during unpredictable and eternal changes (Gunasekaran, 1999). Agile successful firms manage the relationships in the way that use a change position as a tool for profitability (Devor *et al*., 1997).

6.1.1. Human Capability

One of the important parts of the organizations is human resources department. They can make the firm more powerful by their activity and knowledge. Bilateral knowledge development by employees of supplier and customers can make the firm more agile. Teece (1998) has defined human capability as ‘‘the ability to sense and then to gain complete mastery of new opportunities, and to identify and protect the knowledge assets, competencies and complementary assets and technologies.’’ We define Human capability as the ability to recognize new opportunities and threats and teach organizations to cope with

these external outcomes using skills and knowledge of the Human resources. The sub-criteria of Human Capability are:

1. Human Resource Quality (Luo *et al*., 2009; Punniyamoorthy *et al.*, 2011; Sarkar and Mohapatra, 2006).
2. Organizational Learning (Gencer and Gurpinar, 2007; Kogut and Zander, 1992; Luo *et al*., 2009).
3. Team Structures (Croom, 2001; Krishnan and Ulrich, 2001; Yauch, 2007).

6.1.2. Technological Capability

A number of studies have considered technological capability as an important metric for supplier selection procedure (Bhattacharya *et al*., 2010; Choi and Hartley, 1996; Choy and Lee, 2002; Kannan and Haq, 2007; Lee *et al*., 2001). Technology means knowledge about doing practical things, chiefly producing things (In a modern environment, this must include both goods and services). It is believed to be one of the important supplier selection criteria. The important sub-criteria of Technological Capability are:

1. Communication and E-Commerce System (Guo *et al.,* 2009; Katsikeas *et al.*, 2004; Lin *et al.*, 2011).
2. Capability of RandD and Innovation (Chen, 2011; Katsikeas *et al.*, 2004; Lee *et al.*, 2009).
3. Production Facilities and Capability (Dickson, 1966; Punniyamoorthy *et al.*, 2011; Weber *et al*., 1991).

6.1.3. Managerial System Capability

Managerial systems are the core of capability when they constitute different skills and/or when they foster beneficial behaviors not observed by rival firms (Leonard-Barton, 1992). Leonard-Barton (1992) has defined managerial systems interaction capability as ‘‘Formal and informal ways of creating knowledge and controlling knowledge’’. Another definition is presented by Teece (1998) which defines it as ‘‘the ability to strategize'. The sub-criteria of Managerial System Capability are:

1. Quality System (Choi and Hartley, 1996; Dulmin and Mininno, 2003; Hsu and Hu, 2009).
2. Financial Capability (Choi and Hartley, 1996; Punniyamoorthy *et al.*, 2011; Vinodh *et al.*, 2011).
3. Information Sharing Level (Hajji *et al.*, 2011; Krause *et al.*, 2007; Luo *et al.*, 2009).

6.1.4. Cultural Capability

Culture refers to the degree in which norms of behavior govern relationships, whereas congruent goals represent the degree in which parties share a common understanding and approach to the achievement of common tasks and outcomes (Villena *et al.*, 2011).The sub-criteria of Cultural Capability are:

1. Communication Openness (Choi and Hartley, 1996; Ngai *et al.*, 2004; Wang, 2010).
2. Vendor Image (Katsikeas *et al*., 2004; Punniyamoorthy *et al*., 2011).
3. Mutual Trust (Amin *et al*., 2011; Punniyamoorthy *et al.*, 2011 ; Zhang *et al*., 2011).

6.2. Lean perspective

Many enterprises have pursued the lean thinking paradigm to improve the efficiency of their business processes. Leanness means developing a value stream to eliminate all waste, including time, and to ensure a set level (Ben Naylor *et al*., 1999). Leanness may be an element of agility in certain circumstances, but it will not enable the organization to meet the precise needs of the customers rapidly (Agarwal *et al*., 2006). Ho *et al*. (2010), reviewed methods supporting supplier selection problems since 2000 to 2008. They concluded that the most popular criterion in previous researches are quality, followed by delivery, price/cost. More criteria can be considered for lean suppliers, however, solving the problem becomes hard and confusing, and hence we use three criteria for selecting lean suppliers. They are discussed below.

6.2.1. Quality

Companies in today’s highly competitive marketplace are forced to deliver goods or services with prominent privilege to make the costumers satisfied. Quality is the most important criterion that influences

the issue of supplier selection for each kind of materials and products. Many authors have exclaimed that different aspects of quality can influence the performance of suppliers (Chang *et al*., 2007; Choi and Hartley, 1996; Dickson, 1966; Swift, 1995; Weber and Current, 1993). The sub-criteria of Quality are:

1. Warranties and Claim Policies (Dickson, 1966; Guo *et al*., 2009; Kuo *et al.*, 2010).
2. Product Durability (Cannon *et al.*, 2011; Tam and Tummala, 2001; Xia and Wu, 2007).
3. Product Performance (Cannon *et al.*, 2010; Punniyamoorthy *et al.*, 2011; Wang, 2010).

6.2.2. Cost

Cost has been the first metric for selecting suitable supplier issue from the past until now. Purchasing department can play a key role in cost reduction, and supplier selection is one of the most important functions of purchasing management. Cost is the most important index for purchasing department of company; thus, it can be an appropriate measure for evaluating the suppliers. Many of the previous researchers have considered cost and its derivations as a metric for ponder the supplier's efficiency (Choi and Hartley, 1996; Dickson, 1966; Hou and Su 2006; Swift, 1995; Weber *et al*., 1991). Three important costs distinctive are:

1. Product Prices (Chang *et al*., 2011; Choi, Lee and Lo, 2003; Punniyamoorthy *et al*., 2011).
2. Logistics cost (Ghodsipoor and Obarin, 2002; Inman *et al*., 2011; Punniyamoorthy *et al.,* 2011).
3. Payment Terms (Punniyamoorthy *et al*., 2011).

6.2.3. Delivery

Delivery has attracted great attention of researchers in supplier selection problems (Choi and Hartley, 1996; Dickson, 1966; Swift, 1995; Weber *et al*., 1991). It refers to both the supplier's logistical performance as well as the critical activities and the process that is performed from the time of Order entry until it is reached the hands of the consumer (i.e., order fulfillment), it can also influence the business customer's costs, pace of market, and/or the received evaluation of the issue perceived by the end user (Bharadwaj, 2004). Delivery has four sub-distinctive that are:

1. Lead Time (Kuo *et al*., 2010; Chen, 2011; Lin *et al*., 2011).
2. On-Time Delivery (Chen, 2011; Vinodh *et al.*, 2011; Xia and Wu, 2007).
3. Safety and Security (Punniyamoorthy *et al.*, 2011; Wang, 2010).
4. Appropriateness of the packing (Dickson, 1966; Punniyamoorthy *et al.*, 2011; Wang, 2010).

7. Conceptual model of research

The basic conceptual model of research is as follows. This model represents the main criteria (Agility and leanness) and also each sub-criterion and combining both of them to choose the best supplier (suppliers) of raw materials during the review of this research. The model that examined in this study is shown in Figure1.

8. Data analysis method and providing a model

To determine the importance of each criteria of agility and leanness of supplier, AHP method has been used. To accomplish this phase, according to the subset of each criterion, agility and leanness, pair wise comparisons questionnaire was designed that filled by purchasing manager, chief executive officer and vice-manager. Then by using software, the weight of each criteria and their subset was determined, and due to measures, the importance of each criteria was found. To determine the best supplier, a questionnaire provided for evaluation the capability of each supplier in surveyed firms according to the obtained weight for each of indicators in AHP method, TOPSIS method used for best supplier selection for each Company.

8.1. Determining the coefficient of importance of criteria from the perspective of Nilou Tile Company

By using Expert Choice software, the importance of each criteria and sub-criteria achieved for the target firm. Table1 has shown the importance of each criteria and sub-criteria.

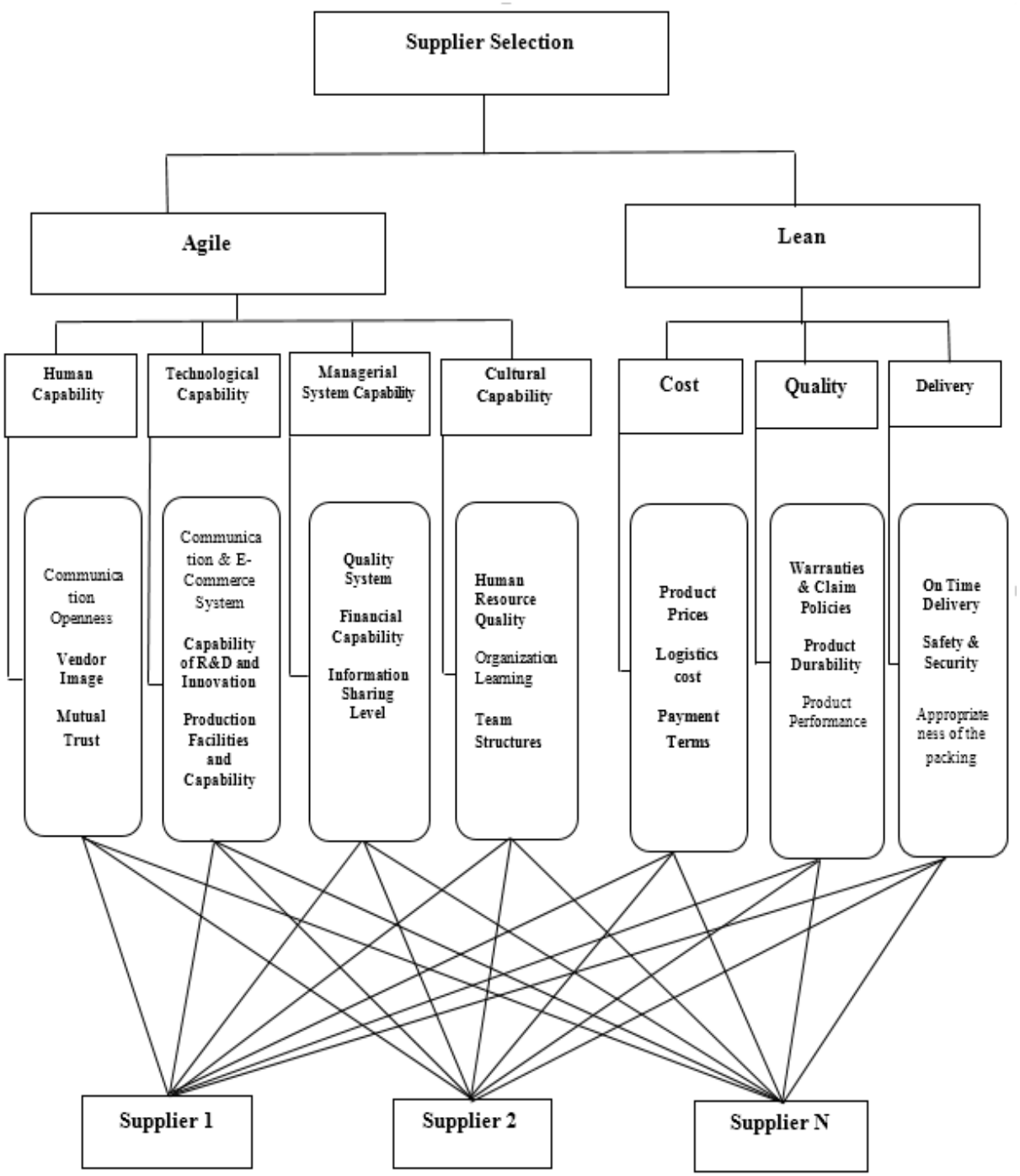

Figure 1. Conceptual model of research

Table 1. The importance of criteria and Sub-criteria in Nilou Tile Company

Sub-criteria	Weight	Criteria	Weight	Dimensions
Human Resource Quality	0.017			
Organization Learning	0.017			
Team Structures	0.055	Cultural Capability	0.176	
Communication and E-Commerce System	0.019			**Agile**
Capability of RandD and Innovation	0.07	Technological Capability	0.25	
Production Facilities and Capability	0.036			

Sub-criteria	Weight	Criteria	Weight	Dimensions
Quality System	0.132	Managerial System Capability	0.485	
Financial Capability	0.072			
Information Sharing Level	0.039			
Communication Openness	0.08	Human Capability	0.088	
Vendor Image	0.08			
Mutual Trust	0.027			
Warranties and Claim Policies	0.092	Quality	0.48	Lean
Product Durability	0.085			
Product Performance	0.084			
Product Prices	0.043	Cost	0.323	
Logistics cost	0.026			
Payment Terms	0.092			
On-Time Delivery	0.036	Delivery	0.197	
Safety and Security	0.041			
Appropriateness of the packing	0.021			

8.2. Determining the coefficient of importance criteria from perspective of Isfahan Tile Company

After polling contributors in Isfahan Tile Company and conclusion and combining them, the importance of each criterion from perspective of this Company was obtained. Table2 displayed coefficient of importance criteria from the perspective of Isfahan Tiles Company.

*Table 2.*The importance of criteria and Sub-criteria in Isfahan Tile Company

Sub-criteria	Weight	Criteria	Weight	Dimensions
Human Resource Quality	0.029	Cultural Capability	0.277	Agile
Organization Learning	0.027			
Team Structures	0.08			
Communication and E-Commerce System	0.033	Technological Capability	0.53	
Capability of RandD and Innovation	0.139			
Production Facilities and Capability	0.093			
Quality System	0.023	Managerial System Capability	0.138	
Financial Capability	0.027			
Information Sharing Level	0.019			
Communication Openness	0.08	Human Capability	0.055	
Vendor Image	0.06			
Mutual Trust	0.013			
Warranties and Claim Policies	0.111	Quality	0.48	Lean
Product Durability	0.206			
Product Performance	0.072			
Product Prices	0.011	Cost	0.137	
Logistics cost	0.007			
Payment Terms	0.051			
On-Time Delivery	0.019	Delivery	0.083	
Safety and Security	0.017			
Appropriateness of the packing	0.006			

8.3. Determining the coefficient of importance criteria from the perspective of Kaveh Tiles Company

After checking and polling contributors in Kaveh Tiles Company, the criteria importance was obtained from this Company's perspective. Table 3 displayed the criteria importance from perspective of Kaveh Tiles Company.

Table 3. The importance of criteria and sub-criteria from the perspective of Kaveh Tiles Company

Sub-criteria	Weight	Criteria	Weight	Dimensions
Human Resource Quality	0.021	Cultural Capability	0.163	Agile
Organization Learning	0.032			
Team Structures	0.029			
Communication and E-Commerce System	0.08	Technological Capability	0.396	
Capability of RandD and Innovation	0.033			
Production Facilities and Capability	0.139			
Quality System	0.103	Managerial System Capability	0.485	
Financial Capability	0.053			
Information Sharing Level	0.022			
Communication Openness	0.011	Human Capability	0.085	
Vendor Image	0.01			
Mutual Trust	0.021			
Warranties and Claim Policies	0.113	Quality	0.506	Lean
Product Durability	0.102			
Product Performance	0.037			
Product Prices	0.065	Cost	0.323	
Logistics cost	0.036			
Payment Terms	0.064			
On-Time Delivery	0.024	Delivery	0.166	
Safety and Security	0.039			
Appropriateness of the packing	0.02			

8.4. Determining the coefficient of importance of criteria from the perspective of Asia Tiles Company

After checking and polling contributors in Asia Tiles Company, the criteria importance was obtained from this Company's perspective. Table 4 displayed the criteria importance from perspective of Asia Tiles Company.

Table 4. The importance of criteria and sub-criteria from the perspective of Asia Tiles Company

Sub-criteria	Weight	Criteria	Weight	Dimensions
Human Resource Quality	0.016	Cultural Capability	0.212	Agile
Organization Learning	0.031			
Team Structures	0.058			
Communication and E-Commerce System	0.058	Technological Capability	0.472	
Capability of RandD and Innovation	0.118			
Production Facilities and Capability	0.06			
Quality System	0.09	Managerial System Capability	0.26	
Financial Capability	0.024			
Information Sharing Level	0.015			
Communication Openness	0.005	Human Capability	0.057	
Vendor Image	0.008			
Mutual Trust	0.016			
Warranties and Claim Policies	0.091	Quality	0.664	Lean
Product Durability	0.162			
Product Performance	0.078			
Product Prices	0.022	Cost	0.25	
Logistics cost	0.013			
Payment Terms	0.091			

On-Time Delivery	0.015	Delivery		
Safety and Security	0.018			
Appropriateness of the packing	0.01		0.086	

8.5. Determining the coefficient of importance of criteria from the perspective of Marjan Tiles Company

In checking and polling contributors in Marjan Tiles Company, after collecting and combining the opinions, the importance of criteria was obtained from the perspective of this Company that its result displayed in Table 5.

Table 5. The importance of criteria and sub-criteria and sub-criteria from the perspective of Marjan Tiles Company

Sub-criteria	Weight	Criteria	Weight	Dimensions
Human Resource Quality	0.069	Cultural Capability	0.339	**Agile**
Organization Learning	0.034			
Team Structures	0.067			
Communication and E-Commerce System	0.035	Technological Capability	0.488	
Capability of RandD and Innovation	0.138			
Production Facilities and Capability	0.072			
Quality System	0.038	Managerial System Capability	0.129	
Financial Capability	0.021			
Information Sharing Level	0.006			
Communication Openness	0.004	Human Capability	0.043	
Vendor Image	0.004			
Mutual Trust	0.014			
Warranties and Claim Policies	0.101	Quality	0.661	**Lean**
Product Durability	0.154			
Product Performance	0.075			
Product Prices	0.053	Cost	0.26	
Logistics cost	0.017			
Payment Terms	0.06			
On-Time Delivery	0.012	Delivery	0.079	
Safety and Security	0.022			
Appropriateness of the packing	0.006			

9. Identifying and ranking the firm suppliers

To answer the second question about rating and determining the best supplier for each of these Companies, first by interviewing participants of each Company the best suppliers were determined in field of color and glaze of tiles and ceramic. After determining the best supplier of color and glaze of tiles in listed Companies, data were collected by questionnaire and used TOPSIS method for analyzing.

10. Calculating the rate of firm's supplier

After nominating criteria, for using TOPSIS method, first the decision matrix was formed according to the answers given by participants, and after normalizing and weighting based on the weight of importance criteria obtained from AHP method, the suppliers were ranked by TOPSIS method through Excel software. Table 6 displayed steps of this procedure from ranking suppliers of Nilou Tile Company to determining the highest and lowest values of each indicator. It should be noted that in these calculations, the related value of two Sub-criteria, product price (*M16*) and transportation costs (*X17*) respectively have been considered with negative coefficient due to the regressive nature of these two criteria.

Continuing the process of calculation related to the rank determination of suppliers in Nilou Tile Company, d+ and d- values for each firm were calculated then with calculation *Ci*, the rank of each suppliers was obtained. Table 7 displayed these calculations as well as the total percent in rank of each firm for Nilou Tile.

Table 6. Calculation of supplier rate of Nilou Tile Company by TOPSIS method

	Iran Glaze	Mashhad Glaze Co	Goharan Glaze Co	Kimia Razi Co	Wi	Normalized and	Normalized and	Normalized and	Normalized and	Max Xi	Min Xi
X1	5	6	4	5	0.017	0.008416	0.0101	0.006733	0.008416	0.0101	0.006733
X2	4	7	4	5	0.017	0.006605	0.011558	0.006605	0.008256	0.011558	006605.0
X3	6	6	5	6	0.055	0.028615	0.028615	0.023846	0.028615	0.028615	0.023846
X4	1	1	1	1	0.019	0.0095	0.0095	0.0095	0.0095	0.0095	0.0095
X5	5	4	5	5	0.07	0.03669	0.029352	0.03669	0.03669	0.03669	0.029352
X6	5	6	5	6	0.036	0.016296	0.019556	0.016296	0.019556	0.019556	0.016296
X7	3	4	3	4	0.132	0.069935	0.069935	0.052451	0.069935	0.069935	0.052451
X8	3	6	6	6	0.072	0.019969	0.039938	0.039938	0.039938	0.039938	0.019969
X9	3	4	3	4	0.039	0.016546	0.022062	0.016546	0.022062	0.022062	0.016546
X10	2	4	4	4	0.08	0.022188	0.044376	0.044376	0.044376	0.044376	0.022188
X11	5	5	5	5	0.08	0.04	0.04	0.04	0.04	0.04	0.04
X12	3	5	6	5	0.027	0.00831	0.013851	0.016621	0.013851	0.016621	0.00831
X13	3	4	6	5	0.092	0.029762	0.039682	0.059524	0.049603	0.059524	0.029762
X14	4	5	6	6	0.085	0.031985	0.039981	0.047977	0.047977	0.047977	0.031985
X15	4	4	5	5	0.064	0.02827	0.02827	0.035338	0.035338	0.035338	0.02827
X16	2	4	5	3	0.043	0.011703	0.023406	0.029258	017555.0	0.011703	0.029258
X17	5	3	5	4	0.026	0.015011	0.009007	0.015011	0.012009	0.009007	0.015011
X18	3	5	5	5	0.092	0.030114	0.05019	0.05019	0.05019	0.05019	0.030114
X19	4	3	4	3	0.036	0.020365	0.015274	0.020365	0.015274	0.020365	0.015274
X20	3	4	4	4	0.041	0.016292	0.021722	0.021722	0.021722	0.021722	0.016292
X21	5	5	4	5	0.021	0.011007	0.011007	0.008806	0.011007	0.011007	0.008806

Table 7. The obtained results from data analysis of Nilou Tile's suppliers ranking

Kimia Razi Co	Goharan Glaze Co	Mashhad Glaze Co	Iran Glaze Co	Supplier
0.013748	0.027467	0.027055	0.051852	d+
0.051317	0.051613	0.044689	0.026908	d-

0.788703	0.652673	0.62289	0.341646	Ci
%33	%27	%26	%14	Total percent

The calculation that related to Isfahan Tile Company suppliers was done by Excel software, and the final results were shown in Table 8 with *Ci* value and overall rate in raw material supply.

Table 8. The results of data analysis of Isfahan Tile suppliers ranking

Yazd Glaze Co	Kimia Razi Co	Setareh Meybod Glaze Co	Mashhad Glaze Co	Iran Glaze Co	Supplier
0.375243	0.678813	0.404992	0.754202	0.463327	Ci
%14	%26	%15	%28	%17	Total percent

After interviewing and collecting the questionnaire from contributors in Kaveh Tile Company, the obtained data were inserted in software and the output was obtained that were suppliers ranking which has shown in Table 9.

Table 9. The results of data analysis of Kaveh Tile suppliers ranking

Setareh Meybod Glaze Co	Yazd Glaze Co	Iran Glaze Co	Supplier
0.832758	0.255827	0.416955	Ci
%55	%17	%27	Total percent

After data analysis in software, each supplier's rate was obtained from Marjan Tile Company, the results of this analysis was shown in Table 10.

Table 10. The results of data analysis in Marjan Tile suppliers ranking

C-Clouid Co	Noutseti Co	Fit-Net Co	C-Chi Co	Setareh Meybod Glaze Co	Supplier
0.66746	0.842685	0.66742	0.537484	0.157315	Ci
%23	%29	%23	%19	%6	Total percent

After interviewing participants in Asia Tile Company, the rate of each supplier obtained from Asia Tile Company. The result of this analysis was shown in Table 11.

Table 11. The results of data analysis of Asia Tile supplier ranking

Kimia Razi Co	Shahr-e-Cord Glaze Co	Yas Glaze Co	Iran Glaze Co	Supplier
0.964937	0.044844	0.591337	0.716357	Ci
%42	%2	%25	%31	Total percent

10. Conclusion based on the results analysis

Considering the ranking of criteria and sub-criteria, it can be concluded that for all surveyed companies the most important criteria are warranty and replacement policy, capability of research, development and innovation, product durability.

From this perspective, it can be deduced that due to the competitive nature of this industry, the need for change and innovation is strongly felt. If, besides these two, there exist the criteria of the standard warranty, replacement and durability of the product, which themselves indicate the product quality, the company will succeed in competitive market and satisfy the various needs of the customers. This is one of the functions of agile production.

The results also revealed that although some suppliers among the surveyed companies are the same, considering the companies' status in financial, structure and technology of product, the view towards these suppliers are different. In addition, the study showed that considering the same rank of product of laced suppliers, the surveyed companies have special attention to the management and cost aspects due to its

importance in the competitive field of company(whether in terms of cost of production, transportation costs or other costs).

In this study each criteria and sub-criteria was examined individually. Therefore, as a suggestion for future studies, it would be beneficial if the relation between criteria and sub-criteria is scrutinized. Moreover, it is useful to examine the other factors of agility and leanness that were not considered in this study. It is recommended that future researches use other aspects and concepts in business. The fuzzy numbers can be applied in AHP and TOPSIS which lead to efficient analysis of data. It is also recommended that other data analysis approaches are applied with regard to what used in this study.

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