Uncertain Supply Chain Management 3 (2015) 231–240

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

Supplier selection in an agent based pharmaceutical supply chain: An application of TOPSIS and PROMETHEE II

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C H R O N I C L E

Article history:
Received December 18, 2014
Accepted March 26 2015
Available online
April 5 2015

Keywords:
Supply Chain
Supplier selection criteria
Agent based Supply chain
TOPSIS
PROMETHEE

A B S T R A C T

Having a supply chain is an unavoidable fact and all companies should focus on if they wish to survive in the competitive business world. This paper ranks criteria influencing on behavior of a medicine manufacturer agent when its goal is to select the supplier agents to interact with across a pharmaceutical agent based supply chain. The pharmaceutical industry is important for countries due to the distinguished role of health in societies and Iran is not an exception too. Besides, the industry in this country is encountered with some limitations because of the situation imposed by sanctions. In this study, first, ten criteria were selected based on expert's opinions, two categories of quantitative as well as qualitative criteria were chosen for ranking the criteria and then TOPSIS and PROMETHEE Π methods were applied to rank the criteria. According to the results of this survey, qualitative criteria were determined as important factors influencing on supplier selection.

1. Introduction

These days, we confront a changing world and the business realm is not an exception. But the only thing that is not altering is the change itself. There are many reasons, which could lead to changes happening in the business field. To be progressive, business owners have to adjust their business under unstable circumstances. Having a supply chain (SC) can be a fruitful way for organizations to survive. Nowadays, the nature of competition is modified from company versus company to SC versus SC (Fu et al., 2000). Moreover, in today's global market place, individual organizations no longer compete as entities, which are autonomous, but rather as integral part of supply chain links. The final victory of a firm will depend on its managerial ability to integrate and coordinate the complex network of business relationship across SC members (Lambert & Cooper, 2000).These are some reasons indicating the importance of supply chain. The supply chain domain is a rich area for sophisticated researches (Mustapha et al., 2010). Supplier selection, supplier evaluation, and investigating criteria influencing on communication between suppliers and manufacturers encompass a vast field for researchers to do their studies in SC territory.

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doi: 10.5267/j.uscm.2015.4.001

Agent technology is a new approach, which can be exploited in many industries (Chaib-draa & Müller, 2006). Agents are applied for designing or simulating complex systems (Mustapha et al., 2010). Multi agent systems consist of heterogeneous agents interacting each other. Moreover, a supply chain may be comprised of multiple stakeholders having their own suppliers, manufacturers, distributers, third party logistics providers, retailers, and customers (Min & Zhou, 2002). These are some but not all reasons proving the supply chain complexity and manifesting the agent technology utilization is proper to supply chain scope. The reasons indicating why the agent based technology is present in supply chain are explained more during next parts.

For many years, the prevalent approach to supplier selection has been to select suppliers only based on the price. However, as firms have apprehend that the emphasis on price just as a single criterion for supplier selection is not effective, they have turned into selecting their suppliers by means of multi-criteria approach (Pal et al., 2013). Keeping in view the both importance of supplier selection and application of agent based systems in supply chain, we concentrate on ranking criteria impacting the behavior of manufacturer agent when it is going to select agents supplying materials in an agent based pharmaceutical supply chain. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) methods which are multi attribute decision making (MADM) techniques are used for ranking different suppliers under various criteria. The study has accomplished in field of Iranian Pharmaceutical Industry. This industry was chosen due to the importance of health in societies and the significance role of supplying medicines in health context. Besides, because of some hardships caused by sanctions imposed on Iran, the pharmaceutical industry in this country faces lots of limitations causing difficulty for partners involving across a pharmaceutical supply chain. Ranking the supplier selection criteria is beneficial for Iranian medicine manufacturers to select the supplier more effectively and to manufacture medicines more on-time. The result of this study can be applied for developing countries where the same Iranian pharmaceutical situation is governed on their pharmaceutical industry. There are literally many studies accomplished in field of supplier selection in supply chain (Weber et al., 1991; Tahriri et al., 2008; Pal et al., 2013). Pearson and Ellram (1995) performed an empirical investigation for supplier selection and evaluation in electronic firms. Degraeve et al. (2000) evaluated suppliers in terms of cost of ownership perspective. Lee et al. (2001) proposed a methodology for identifying the managerial criteria using information derived from the supplier selection processes in the supplier management process. Humphreys et al. (2003) proposed a framework for integrating environmental factors into the supplier selection process. They also presented a decision support tool helping companies to integrate environmental criteria into their supplier selection process and a knowledge-based system was constructed based on the proposed framework. Svensson (2004) investigated some models for supplier segmentation and supplier selection criteria. Chen-Tung and Ching-Torng (2006) used a fuzzy approach for supplier evaluation and selection in supply chain management. Sanayei et al. (2008) proposed an integrated approach of multi-attribute utility theory and linear programming for rating and choosing the best suppliers. Moreover, the optimum order quantities among selected ones was defined in order to maximize total additive utility. Boran et al. (2009) proposed a multi-criteria intuitionistic fuzzy group decision making for supplier selection using TOPSIS method.

A Supply chain is defined as an integrated system that synchronizes a series of inter-related business process in order to 1) provide raw materials and parts 2) transform these raw materials and parts in to finished products 3) add value to the products 4) distribute goods to the retailers or customers 5) comfort information exchange across supply chain elements (like supplier, manufacturer, third- party logistic providers, and retailers). Its main goal is to enrich operational efficiency, profitability, and competitive position of a company. Briefly, supply chain management is defined as “the integration of key business processes from end users through original suppliers preparing products, services and information and adding value for customers and stakeholders” (Cooper et al., 1997). A supply chain is described by forward flow of goods and backward flow of information as shown by Fig. 1. (Min & Zhou, 2002).

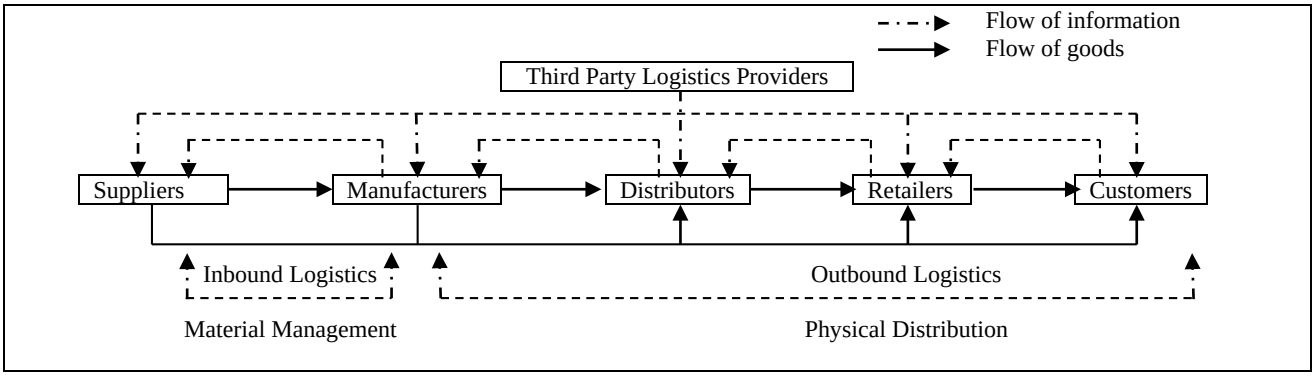

Fig. 1. A supply Chain with forward flow of goods and backward flow of information

Suppliers are initiation points of a supply chain. They are organizations or companies providing raw materials and manufacturers' needs to produce goods. The suppliers of a supply chain can be manufacturers in other supply chain (Rushton et al., 2006). In most industries, the largest percentage of the total product cost is allocated to the costs of raw materials and component parts. Therefore, selecting the right suppliers is momentous to procurement process; its breakthrough is a major opportunity for firms to decrease costs along their whole supply chains. Furthermore, efficient supplier selection reduces the purchase risks (Pal et al., 2013). Nowadays, many industries use different techniques to improve their businesses such as concurrent engineering, collaborative engineering design, manufacturing enterprise integration, SC management, manufacturing planning, scheduling and control, material handling, and holonic manufacturing systems exploit agent technology (Chaib-draa & P.Müller, 2006). This technology has absorbed lots of attention for exceptional research activities during previous years. As in every technology, the agents possess a variety of special skills thus they are fruitful for distributed, unstructured and decentralized architectures which are complicated due to changes (Andreadis et al., 2014). The term "agent" defines a hardware or (more usually) software-based computer system that has the following characteristics:

1. Autonomy: agents operate without the direct intervention of humans or others, and have some kind of control over its actions and internal state;
2. Social ability: agents interact with other agents (and possibly humans) by some kind of agent-communication language;
3. Reactivity: agents perceive their environment[1], and respond in a well-timed way to changes that occur in it;
4. Pro-activeness: agents are able to exhibit goal- directed behavior by taking the initiative (Wooldridge & Jennings, 1995).

Agents communicate, collaborate, coordinate and negotiate in a system designed and implemented as a multi-agent system (Andreadis et al., 2014). Supply Chains are comprised of production subsystems, which are heterogeneous and gathered in vast dynamic and virtual coalitions, where each element (or production subsystem) has its own individual goals, while satisfying both local and external constraints. In addition, the distributed manufacturing units have four characteristics including Autonomy, social ability, reactivity and pro-activeness. Agent technology and particularly multi agent systems have been created for dealing with such characteristics. Besides, multi agent systems propose a path for realizing systems that are decentralized rather centralized, emergent rather planned, and concurrent rather

[1] The environment may be the physical world, a user, a collection of other agents, the Internet, or perhaps all of these combined.

sequential, and this is what characterizes SC systems generally. It is the rationale behind choosing such technology in SC management scope (Chaib-draa & Müller, 2006).

According to the mentioned explanation, suppliers, manufacturers, distributors, and customers can be considered as agents having the goal-directed behavior, acting to the other agents, responding to the environment while they are autonomous. For example in a three layer supply chain supplier, agents are the agent of the first layer, manufacturer agent is associated with manufacturing layer, and distributer agents are agents of distribution layer. Fig. 2 manifests an agent based supply chain model in which agents interact with each other based on a blackboard mechanism. Each agent interacts and shares information through a blackboard (Ito & Salleh, 2000). To give an instance, for an Iranian pharmaceutical supply chain, it can include the information of status quo governing on the pharmaceutical industry impacting the interactions between supplier and manufacturer agents like information which affects the supplier selection behavior of a manufacturer agent.

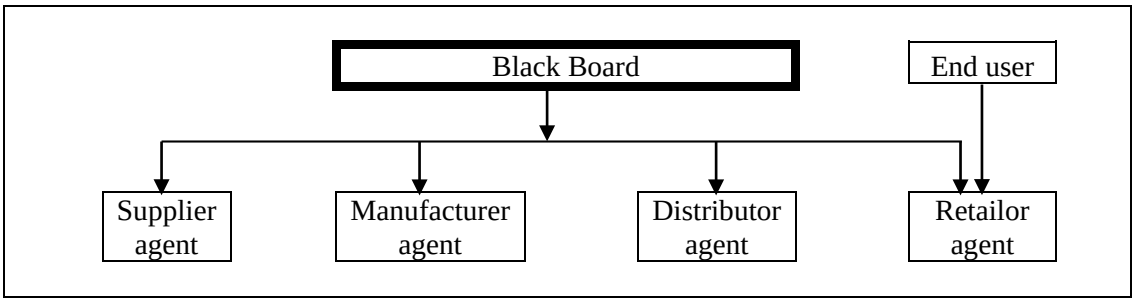

Fig.2. An agent based model of a supply chain (Chaharsooghi et al., 2005)

2. Materials and methods

2.1. Research methodology

First, many related articles were studied, and different supplier selection criteria were extracted. Table 1 summarizes the criteria repeated over and over on different studies presented by Degraeve et al. (2004), Humphreys et al. (2003), Araz et al. (2007), Dickson (1996), Dulmin and Mininno (2003), Ghodsypour (1998), Ha and Krishnan (2008), Ho (1998), Liu et al. (2005), Muralidharan et al. (2002), Percin (2006), Su and Hou (2007), Ting and Cho (2008). Next, 10 criteria which are more appropriate to pharmaceutical industry were selected based on five experts' ideas and Fig. 4 represents the criteria. Next, a questionnaire was designed for data gathering. Finally, the criteria were ranked by applying PROMETHEE II and TOPSIS, and the derived results were compared to each other.

Table 1
Supplier selection criteria derived from different articles

Quality	Costs	Functional control	Brand
On-time delivery	Business plan	After sale services	Supplier position
Customer complaints management	Price	Personnel behavior	Duration of delivery time
Executive experiences	Customer relationship	Level of technology used	Innovation
Reputation	Ability to design products	Management	Working Capital
Interest to the business	Transportation process	Organizational culture	Previous Cooperation experience
Organization management	Transportation costs	Research and development (R&D)	Reliance
Financial Status	Flexibility	Technical situation	Professional sale personnel
Services	Amount of material can be provided	Personnel training	Safety
Organizational culture	Previous Cooperation experience		

2.2. TOPSIS and PROMETHEE

There is not always a single definite criterion of selection to make a perfect decision. In other words, lots of criteria such as technological, economic, ethical, political, legal, and social factors should be considered by decision makers in order to make an advantageous decision. Multiple Objective Decision -making (MCDM) provides simple, systematic and logical methods or mathematical tools to guide decision makers when they face a number of criteria and their interrelations. Depending on the domain of alternatives, MCDM problems are subdivided into two categories: Multiple Attribute Decision-making (MODM) and multi-objective decision making (MODM).

MODM techniques have decision variables values that are determined in a continuous or integer domain, with a large number of alternative choices. MADM methods are generally discrete, with limited number of pre-specified alternatives (Gayatri & Chetan 2013). As mentioned before, the both Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Technique for Order Preference by Similarity to Identical Solution (TOPSIS) are MADM techniques applied in this research for ranking the supplier selection criteria.

2.2.1. Technique for Order Preference by Similarity to Identical Solution (TOPSIS)

The TOPSIS method is based on the concepts that the chosen alternative should have the shortest Euclidean distance from ideal solution and the farthest from negative ideal solution (Amponsah et al., 2012). The ideal solution is a presumptive solution for which all attribute values corresponds to the maximum attribute values in the database comprising the satisfying solutions; the negative ideal solutions the hypothetical solution for which all attribute values corresponds to the minimum attribute values in the database (Macharis et al., 2004).

2.2.2. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

The PROMETHEE technique deals with evaluation and selection of a set of actions[2] based on several criteria to obtain a ranking among them. This method can simultaneously deal with quantitative and qualitative criteria. It was established by Brans and Vincke in 1985 (Ito & Salleh, 2000). The logic behind it is based on the comparison of each alternative with each other considering the deviations those alternatives show according to each criterion (Caterino et al., 2008). PROMETHEE Π is used to rank the actions by total pre-orders (Complete ranking without incomparability)**.** Based on this method**,** a total pre-order has been requested by the decision-maker.

3. Results and discussion

3.1 Ranking the criteria based on TOPSIS

In this study, 10 criteria were considered as the alternatives and 126 respondents were considered as attributes. Fig. 3 displays the hierarchical structure of the Decision making problem. To rank the criteria via this method, a decision making matrix was created which has 10 rows and 126 columns. Due to the large size of the matrix, a part of that is shown on Table 2.

[2] Actions are the decision making alternatives, which are the supplier selection criteria on this research.

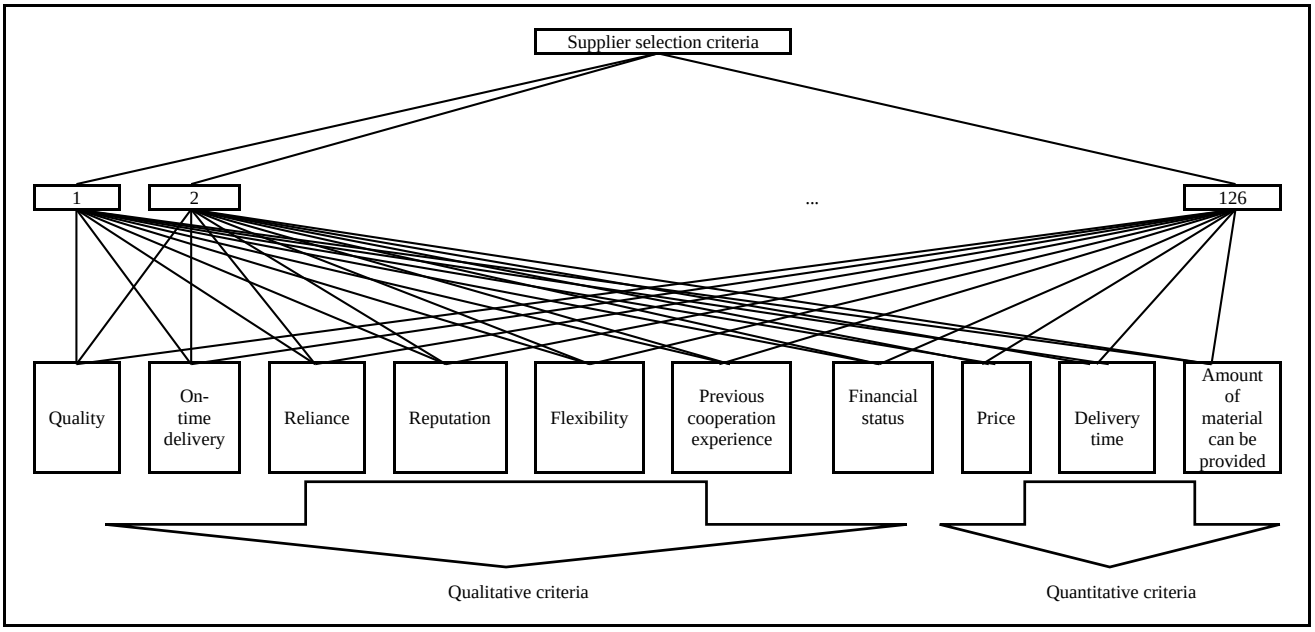

Fig. 3. The hierarchical structure of decision making about supplier selection criteria ranking

Table 2
A part of the decision making matrix

			Attributes		
Alternatives	**Respondent1**	**Respondent2**	**Respondent3**	**…..**	**Respondent126**
Quality	4	4	5	…..	3
On-time delivery	4	4	4	…..	4
Reliance	4	4	3	…..	3
Reputation	4	4	3	…..	3
Flexibility	3	1	4	……	3
Previous cooperation experience	4	5	5	…..	
Financial status	4	5	5	…..	3
Price	4	4	5	…..	4
Duration of delivery time	5	4	5	…..	3
Amount of material can be provided	5	5	4	…..	2
Weights	0.0079365	0.0079365	0.0079365	…..	0.0079365

After creating decision matrix, the normalized decision matrix and weighted normalized decision matrix were constructed. Then, negative ideal solution and ideal solutions were defined. Next, the separation measures from ideal solution (S_i^+) and negative ideal solution (S_i^-) were calculated. In this step, the relative closeness to the ideal solution (C_i) was calculated too. Finally, the C_is were sorted and the alternatives were ranked. You can follow the outcomes of these calculations on Tables 3-4.

Table 3
Separation measures from ideal solution and negative ideal solution and the relative closeness to the ideal solution (C_i)

	S_i^+	S_i^-	C_i
Quality	0.00530817	0.011756729	0.688942
On-time delivery	0.007794566	0.01122093	0.590094
Reliance	0.009428069	0.007664598	0.448414
Reputation	0.009353542	0.007755372	0.453294
Flexibility	0.011450867	0.006241124	0.352765
Previous cooperation experience	0.006584995	0.011299659	0.631808
Financial status	0.008516566	0.008694492	0.505169
Price	0.005566211	0.012203525	0.686759
Duration of delivery time	0.005829043	0.011779336	0.668962
Amount of material can be provided	0.008391331	0.01152382	0.578646

Table 4
Ranked criteria based on TOPSIS

Rank	Alternative	C_i
1	Quality	0.688942204
2	Price	0.686758959
3	Duration of delivery time	0.668961982
4	Previous Cooperation Experience	0.631807524
5	On-time delivery	0.590093985
6	Amount of materials can be provided	0.578645875
7	Financial Status	0.505168937
8	Reputation	0.453294238
9	Reliance	0.448414407
10	Flexibility	0.352765493

3.2. Ranking the criteria based on PROMETHEE II

To rank the criteria, Visual PROMETHEE software was used and the preference flows and net flows were calculated. The analysis outcomes exist on Table 5-7 and Fig. 4.

Table 5
Multicriteria Prefrence Flows

Action	Φ^+	Φ^-	Φ
Price	0,4004	0,1534	0,2469
Duration of delivery time	0,4224	0,2037	0,2187
Amount of materials can be provided	0,2116	0,3501	-0,1384
Quality	0,4233	0,1226	0,3007
Reliance	0,1305	0,4506	-0,3201
Reputation	0,1367	0,4427	-0,3060
Flexibility	0,0970	0,6340	-0,5370

Table 6
Multicriteria Prefrence Flows

Action	Φ^+	Φ^-	Φ
Financial Status	0,3801	0,2231	0,1570
Previous cooperation experience	0,4312	0,2293	0,2019
On-time delivery	0,4109	0,2346	0,1764

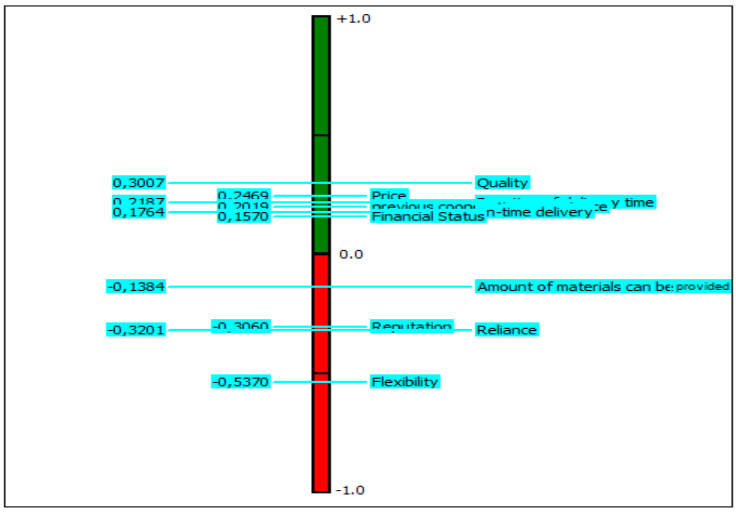

Fig. 4. PROMETHEE Π complete rankings

Table 7
PROMETHEE flow table

Rank	Factor	Φ	Φ^+	Φ^-
1	Quality	0,3007	0,4233	0,1226
2	Price	0,2469	0,4004	0,1534
3	Duration of delivery time	0,2187	0,4224	0,2037
4	previous cooperation experience	0,2019	0,4312	0,2293
5	on-time delivery	0,1764	0,4109	0,2346
6	Financial Status	0,1570	0,3801	0,2231
7	Amount of materials can be provided	-0,1384	0,2116	0,3501
8	Reputation	-0,3060	0,1367	0,4427
9	Reliance	-0,3201	0,1305	0,4506
10	Flexibility	-0,5370	0,0970	0,6340

3.3. Discussion

Significant role of supply chain cannot be ignored. Having a supply chain acting in the best manner is vital in today's competitive business environment because the nature of competition is varied from company versus company to supply chain versus supply chain. Supplier selection provides a playground for researches interested in topics related to supply chain. Agent technology is exploited to design the complex systems like supply chain systems. Each of supplier, manufacturer, distributer, and retailers can be considered as agents due to having the goal-directed behavior, interacting with the other agents, responding to the environment, and autonomy. A blackboard mechanism is a mechanism providing a bed for agents to interact and share information. Thus a black board of an agent based Supply Chain contains lots of information such as information related to interactions between supplier and manufacturer agents. In this study, the supplier selection criteria impacting on behavior of medicine manufacturer agent in interaction with supplier agents were ranked by TOPSIS and PROMETHEE Π Methods. According to the results of both techniques, quality, price, duration of delivery time, previous cooperation experience, and on-time delivery are five most important criteria. In addition, reputation, reliance, and flexibility maintain different rank. The mentioned distinction occurs maybe because of different mathematical approach applied in each method.

The results are rational; the first rank is allocated to quality because individuals are the final customers consuming medicines and it is in direct relation to their life. The sanctions that have been imposed on Iran lead to many limitations on the pharmaceutical industry. Sometimes providing money to supply materials is a problem causing hardships; if government cannot provide needed funds on-time, the manufacturer agent will not receive required materials on-time too, and it will stop working, which could cause a delay for supplying needed medicine in society; it will have some consequences like pressures on patients which reduces customer satisfaction. In addition, if a supplier agent provides supply materials in a shorter amount of time, the manufacturing suspension probability will decrease and the manufacturer agent can respond to demands more on-time too; accordingly and consequently the customers' satisfaction will increase. Moreover, when a manufacturer agent wants to buy materials from a new supplier agent, it should receive and test a sample of material and after its approval, it can buy the needed materials. Thus it would be better for the manufacturer agent to choose supplier agents accompanying it previously. All these reasons justify quality, price, duration of delivery time, previous cooperation experience, and on-time delivery are the most important criteria which have the higher ranks rather than financial status, amount of materials can be provided, reputation, reliance, and flexibility.

4. Conclusion

In conclusion, two groups of criteria impacting the supplier selection behavior of an Iranian medicine manufacturer agent acting across a pharmaceutical agent based supply chain have been considered in this study. The first one contained quality, on-time delivery, reliance, reputation, flexibility, previous cooperation experience, and financial status which were qualitative criteria. The second group included price, duration of delivery time and amount of materials can be provided which were quantitative

criteria. Quality, price, duration of delivery time, previous cooperation experience, and on-time delivery were the first five criteria, and reputation, reliance, and flexibility were criteria which the last three ranks were allocated to them based on both TOPSIS and PROMETHEE Π techniques. Additionally, it can be concluded the qualitative criteria play important roles on supplier selection behavior of a manufacturer agent because two of the three qualitative criteria, price and duration of delivery time, are placed on first five criteria's ranks.

Acknowledgment

We would like to thank Dr. Hamed Sobhani and Mrs. Niloofar Nobari for helping us in data gathering phase. We also sincerely thank Mr. Meisam Pourghahreman for editing the original manuscript.

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