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The effect of resilience for selection of suppliers with hybrid fuzzy mcdm

El efecto de la resiliencia para la selección de proveedores con hybrid fuzzy mcdm

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ABSTRACT

The purpose of this study is to investigate the effect of resilience for the selection as well as ranking suppliers with Fuzzy DEMATEL (Case study: Tabriz Compressor Manufacturing Company). The industrial engineers and production planners of Company were included in this study. For information gathering the questionnaire designed by the researchers was used. The Fuzzy DEMATEL method has been used to investigate the factors affecting resilience in the selection of suppliers. Also, Fuzzy VIKOR and COPRAS-G method has been used to compare and to represent ranking suppliers. Since COPRAS-G approach is used to analyze the different alternatives, and to estimate the alternatives based on their significance, degree of utility and the decision makers' support to make more accurate decisions. In this regard, thirteen criteria have been selected by industrial experts. Based on the results obtained from Fuzzy DEMATEL, cost, quality, delivery time, and risk factor are ranked respectively. Additionally, after comparing Fuzzy Vikor and COPPRAS-G, the results obtained from COPRAS-G showed the best ranked amounts throughout different alternatives. Finally, the results obtained from COPRAS-G showed the traditional criteria in resilience supplier selection ranked the first and supplier selection from the stakeholders' perspectives placed in second order. Furthermore, utility values and ranking candidate alternatives showed that the green supplier (A_5) ranked the first, selection of suppliers (A3) was the next, following the traditional criteria (A_1), supplier criteria(A4), supplier selection from the stakeholders' perspectives (A_2), as the remaining ranks, respectively.

Keywords: Resilience, Selection and ranking Suppliers, Ranking Fuzzy DEMATEL, COPRAS

RESUMEN

El propósito de este estudio es investigar el efecto de la resiliencia para la selección y clasificación de proveedores con Fuzzy DEMATEL (Estudio de caso: Tabriz Compressor Manufacturing Company). Los ingenieros industriales y los planificadores de producción de la Compañía fueron incluidos en este estudio. Para la recolección de la información se utilizó el cuestionario diseñado por los investigadores. Se ha utilizado el método Fuzzy DEMATEL para investigar los factores que afectan a la resiliencia en la selección de proveedores. Además, se ha utilizado el método Fuzzy VIKOR y COPRAS-G para comparar y representar el ranking de proveedores. Dado que el enfoque COPRAS-G se utiliza para analizar las diferentes alternativas y estimar las alternativas en función de su importancia, grado de utilidad y apoyo de los tomadores de decisiones para tomar decisiones más precisas. En este sentido, trece criterios han sido seleccionados por expertos industriales. Con base en los resultados obtenidos de Fuzzy DEMATEL, el costo, la calidad, el tiempo de entrega y el factor de riesgo se clasifican respectivamente. Además, después de comparar Fuzzy Vikor y COPPRAS-G, los resultados obtenidos de COPRAS-G mostraron las cantidades mejor clasificadas entre las diferentes alternativas. Finalmente, los resultados obtenidos de COPRAS-G mostraron que los criterios tradicionales en la selección de proveedores de resiliencia ocuparon el primer lugar y la selección de proveedores desde la perspectiva de las partes interesadas se colocó en segundo lugar. Además, los valores de utilidad y las alternativas candidatas de clasificación mostraron que el proveedor verde (A5) clasificó en primer lugar, la selección de proveedores (A3) fue la siguiente, siguiendo los criterios tradicionales (A1), criterios de proveedor (A4), selección de proveedores desde la perspectiva de las partes interesadas (A2), como los rangos restantes, respectivamente.

Palabras claves: Resiliencia, Selección y ranking Proveedores, Ranking Fuzzy DEMATEL, COPRAS

1. INTRODUCTION

Supply chain systems encounter different disturbing incidents such natural disasters, hurts of human beings resulted from common failures, the growth of global supply alternatives, and strategic external workforce employment. In today's global competitive world, firms tend to outsource their business processes to external organizations and benefit advantages such as low-cost work force, product quality improvement, innovation and creativity in services (Hosseini et al., 2016a). The supply chain is comprised of all sections involved in preparing customers' orders. Today business environment has created some conditions to initiate a high level of lack of assurance and complicated behaviors within the supply chains. Such complicated behaviors result from factors such as globalization, increase of outsourcing the activities, the increase or reduction of demand trend, the reduction of products' life cycle, more reduction in inventories, and the minimization of suppliers of the firms (Jafarnejhad et al., 2016).

With the advent, development, and spread of supply chain management debates, many of the firms have shifted their attention from internal (internal processes of the organization) focus towards external factors and higher and lower levels of members participating within the supply chain. Currently, competition between supply chains is altered for the competition between the organizations and proper management of the supply chain could result in preserving the organization's survival and its profitability. The effective management of supply chains is among the major factors in preserving the survival. The good performance of a supply chain plays the major role in success of an organization and permanent access to the goals, specifically profitability. Meanwhile, the implementation of a supply chain performance measurement terminal is suggested to permanently improve its performance. Supply chain management refers to all processes of the assessment and selection of the suppliers, negotiations on the price and goods delivery, the effects of demands and supplies and (Chopra and Mindel, 2007).

Karimi (2016), has divided decision making in supply chain management into three categories as follows: strategic, tactical, and operational levels. The specific decision making in strategic level refers to the selection, participation, and the design of the supply chain network because it creates the most prevalent effects on network's performance. Preparation complexities (Rao and et al., 2016), production (Torkaman et al., 2017), distribution planning (Bashiri et al., 2016), and optimal order appropriation (Hiloee et al., 2017) are among the most important issues discussed in tactical level. Flexibility could be defined as the ability of supply chain to adjust and prepare for unprecedented destructive incidents and also the capability to rapidly return to the ordinary operations. Today effective planning of the flexible strategies is deemed as a priority for the manufacturers in order to reduce business ambiguities and preserving the self in global competitive environments (Panitas et al., 2020).

Supply chain resilience is known as a comprehensive comparative capability idea to get ready for novel challenges known as unprecedented, responding the disturbances and revival preserving the operations permanently in an optimal level of connection and controlling the structure and the performance (Ponomarof and Holcomp, 2009; Forouzesh et al., 2017). The organizations can create resilience using the following three overall methods: (1) creating redundancy in a supply chain, (2) spread and development of supply chain resilience, and (3) firm culture change (Shafi, 2005). Christopher and Pack (2004) considered different and unique overall rules supporting resilience in supply chain. The selection of the most appropriate supplier is very important within the competitive market for firms that tend to increase the quality and reduce the costs. The selection of suppliers is known as the most important challenge in supply chain management duties and sections under their supervision. Supplier selection is known as a challenging multiple criteria decision-making issue entailing tangible and intangible elements (Hu et al., 2010). Traditionally, the main problems in supplier selection comprise from primary criteria such as: quality, cost, service level, and the time required to deliver services from among other issues (Dickson, 1966; Hosseini et al., 2016a). The goal of choosing the best and most appropriate suppliers from among the set of different alternatives is to suggest proposals and optimal appropriation of the demands among the selected suppliers to satisfy different preparation criteria. Commonly, as pointed out by Hosseini and Barker (2016a), SSP has proposed some more traditional criteria (such as cost, quality, delivery time, responding rate) and recently some green criteria (such as: transportation compatible with the environment, packing, and management) were proposed (Hosseini et al., 2019).

2. A REVIEW OF LITERATURE

Supply chain

A supply chain consists of all sides involved in satisfying the need of a customer directly or indirectly. The supply of chain not only entails the manufacturers and the suppliers, but also it includes transportation, inventories, retailers and even the customers themselves (Choprov et al., 2007).

Supply chain management

Management in a supply chain includes a vast set of activities required for planning, implementation, and controlling production processes, and the delivery from the starting point of the raw materials to the end user point. Supply chain management involves planning and management of all activities related to the supply of resources and preparation, transformation, creation and satisfaction of the demands, and all management activities are logistic. Therefore, it also entails the cooperation with channel partners which includes the suppliers, the intermediaries, the suppliers of third person services and the customers. Principally, the supply chain management unifies supply and demand management within and among the firms. The supply chain management includes vital elements, processes, and testing (Adivibu et al., 2022).

Supply chain performance

The supply chain performance is measured through the use of the model, development, and communications related to each element. SCOR model integrates some of the constituents (For example, business techniques, criteria, and the best business methods). It applies them within the supply chain system to create a comprehensive framework to increase the supply chain management performance (Prativi et al., 2019). Supply Chain Operation Reference (SCOR) is deemed as a method to manage supply chain activities and the processes through this method can be utilized as a practical instruction to analyze supply chain management methods (Lampert et al., 2001; Adivibu et al., 2022). Salehin et al. (2018) suggested a supply chain performance measurement through the literature study in the field.

Resilient supply chain

Currently the resilient supply chain is known as the most vital element in supply chain risk management (Ponomarof et al., 2009) and it has been introduced as a fairly novel research field while an unknown one in management comprehensively as pointed out by Poyns et al. (2012).

The organizational outlook has referred to resilience as a permanent replenishment capacity (Holnagol et al., 2009). Within SCM, flexibility is known as a novel perception emerged during some recent years. Christopher Pack (2004): the ability of a system to return to its primary status or movement to the novel state and more optimal one after the disturbance (Shafi, 2005). Resilient represents the capability of the materials to return back into its original form after reshape. The comparative capability of supply chain refers to the flexibility of a supply chain as a novel overall idea which could be defined as a preparation for unexpected incidents, responses to disorders, and improvements preserving the operation permanence within an optimal connection and control level on the structure and the performance (Ponomarof and Holcomp, 2009). Resilient could be defined as the supply chain capability to adjust and get prepared for unprecedented destructive incidents and also its capability to rapid revival to return to the ordinary operations. The effective planning for flexible strategies is deemed as a priority for manufacturers to reduce business ambiguities and self-preservation within the global competitive environment (Suvior Otanapas et al., 2020).

The supply chain resilience is known as a novel comprehensive idea known as the comparative capability of the supply chain to prepare for unexpected challenges, to respond the disorders and the revival of them through the permanent preservation of the operations in an optimal level of the connection and control over the structure and the performance (Forouzesh and Mokaran, 2017). The organizations can create resilience using the following three overall methods: (1) creating redundancy in a supply chain, (2) spread and development of supply chain resilience, and (3) firm culture change (Shafi, 2005). Christopher and Pack (2004) considered different and unique overall rules supporting resilience in supply chain.

Forouzesh et al. (2017); Jotner and McClan, (2011); Manouch and Mentezer (2008) consider that supply chain resilience could take one of the following four forms: flexibility, speed, view, and cooperation.

Resilience operations

Resilience operations could be observed regarding supply chain operations in a business firm. According to supply chain committee (SCC), all operations carried out through different border levels of a supply chain include five first level processes: planning, resource, production, delivery, and return. Since these operations are not administered in isolated systems, they may have several vulnerability points potentially having lack of certainty or it may halt system’s operational superiority in such cases. Planning usually encounters prediction errors, long prediction horizons, and control difficulties. The source finding could be challenged through a source finding, joint suppliers with the rivals, or the in-time delivery (For example, Shafi, 2007). A resilient operational service is a service that can act in the presence of noise or stress to the mission when the disturbance or stress can return to the normal status. If a service cannot return to the normal status after the noises, it is nor resistant even if it can resist against unfavorable conditions temporarily (Allen, 2010). There are several common characteristics among different definitions. The common key features in the definitions are as follows: the capability of a firm to avoid the occurrence of a critical incident to protect oneself against an undesirable incident. Preserve responding a critical incident and improvement following that and business services when a disturbance occurs (Leo, 2020).

Supply chain resilience measurement criteria

Surely a resilient supply chain shows that a supply chain is formed of qualitative criteria. These criteria are as follows:

Cooperation

Within supply chain, cooperation simply means that the supply chain operation is jointly planned and administered by two or several independent firms for reciprocal benefits (Simatupang and Sridharan, 2008). The motivation adjustment and the decision cooperation play a vital role in establishing the supply chain cooperation to successfully respond to disturbances within an organization (Papadopolos et al., 2017). Shekhar Singh et al. (2019), investigated about operation criteria of flexibility within a supply chain and proposed a conceptual framework.

Consistency

Consistency is totally referred to as the use of resources unable to reduce current problems without using the resources required for the forthcoming generation to reduce their own problems (Huhanstein et al., 2015; Kusrini et al., 2018). Jane et al. (2017) proposed a better understanding of how consistency can help flexibility within a supply chain. Some authors claim that a selection with a better quality and the reduction of wastes and dangers within an organization helps it a lot (Hafez Alco et al., 2018).

Agility

The supply chain agility is defined as a rapid reaction capability towards an irregular change within the supply and demand (Christopher and Pak, 2004). It could be observed that flexibility requires agility for a rapid reaction to random positions and the preservation of an alternative advantage through an unapproved situation (Shikharsing et al., 2019).

Redoing

Redoing includes a vital and serious use of an additional inventory which can be created in emergencies for adjustment, for example to increase the demand (Aghaee et al., 2017), or to target supply shortages (Christopher and Pak, 2004). Also, it can be considered as method to apply flexibility (Erne Hulber, 2015).

Resilience

For resilience, a supply chain should be resilient and it is known as a capability of a supply chain to adjust itself based on the requirements proposed by the partners and the environmental conditions within the least time interval (Stevenson et al., 2007). This literature review has recognized different types of resilience characteristics that can improve SCR. For example, resilient transportation, resilient work plays programs, delays, resilient supply bases, and order satisfaction resilience are among them (Petitet et al., 2013).

Observation capability

Supply chain observation capability is known as the ability of a supply chain manager to observe the two ends and to recognize the disturbing points (Christopher and Pak, 2004). Observation capability is achieved as a broadcasting method and validates the firms in a way that they can adjust their capabilities to constrain the problematic effects (Tong, 2006). Additionally, it presents some data regarding the current status of work resources and supply chain environment using measurements representing key administrations to supervise the administrations (Azadeh et al., 2014).

Sharing capability

Within the supply chain, sharing correct information properly is very desirable and it reduces the risk within the supply chain (Nishat Feisal et al., 2006). Throughout current era dynamic and unidentified supply chain environment, it is very necessary to form a group of active partners to minimize the risk within the supply chain and precise data should be informed among all partners and within a certain group (Setak et al., 2018; Tohidi et al., 2017).

Strength

Strength of the supply chain contradicts with change and entails a preventive expectation of development before it happens (Wiland et al., 2013). The building strength requires a strategic planning to create a supply chain network (Ahrenhunber et al., 2015). A strong supply chain can work while there exist several upsetting effects because it resists and adjusts itself with it when changes occur (Tang, 2006; Shishehbori et al., 2018).

Awareness/Sensitivity

Awareness/sensitivity can be defined as a prediction for the real demands. Awareness/sensitivity involves the supply chain vulnerabilities and the creation of some resolutions for such states. It needs understanding an imaginable disturbance through recognizing and translating the incidents through primary caution systems and cooperation (Jane, 2017). Meanwhile, such activities for creating cooperation requires sharing the data and learning between the same group of supply chain members to create and increase awareness level expecting the disturbances (Mandal, 2014; Shekhar Singh et al., 2019).

Supply chain risk management (SCRM) culture

After globalization in industry and the advent of several added value processes, several changes occur within the supply chain and this is deemed as the root factor of vulnerability within the supply chain (Singsaray and Grigory, 2008). Christopher and Pak (2004) claim that a dynamic supply chain with higher complexities against the disturbances is more honored. To activate supply chain flexibility, first we should be initiative and any organization should employ a member in board of directors who has a proper understanding of risk, SCR element, and the supply chain structure (Choy and Hung, 2002; Komar et al., 2019).

Security

Security is an important element in SCR which should be initiated earlier than other issues instead of searches for it after a section is being fulfilled (Rice and Kaniato, 2003). Additionally, security could be enhanced through creating cooperation with supply chain partners and public and private partners (Singsaray and Grigory, 2008; Komar et al., 2019).

Adjustability

The adjustment capabilities are identified to pave the way for the development and the creation of an appropriate framework to adjust with novel conditions and goals (Jane et al., 2017). If a supply chain is able to adjust easily, it can return to its initial status after disturbances. Supply chain flexibility is focused on all involving cooperation of the whole framework to adjust with temporary problematic situations (Chavdory and Quados, 2016).

Supplier selection

The issue of supplier selection or the selection of a proper supplier deals with appropriate products and appropriate time to minimize total costs and satisfy qualitative and quantitative parameters at the same time. Any business organization depends on suppliers to a great extent. Therefore, suppliers play a vital role in making the organization profitable and benefiting it. Additionally, the suppliers should adopt novel technologies to manufacture products for the supplier organizations in order to optimize total costs. The issue of supplier selection is considered as a challenging multiple criteria decision-making issue including tangible and intangible factors. The goal of supplier selection is to choose the best supplier from among a set of potential suppliers to satisfy certain obligations while being constrained with the related limitations (Dickson, 1996).

Supplier selection regarding the satisfaction of most outstanding requirements for issues related with risk can reduce supply chain vulnerability to a great extent. Resilience is deemed very important as the capability of the system to return to the unique status or the better condition after encountering chaos (Christopher and Pak, 2004). The capability of the suppliers to manage risks (which means to prioritize it to the rivals to manage the disturbances) reveals the resilience of the supplier (Shafi, 2005). Forouzesh et al. (2017) dealt with the selection of resilience suppliers' issue within supply chain using a fuzzy group decision making model using a novel range amount based on probable statistics concepts. Venkatsan and Gove (2016) created a multiple purpose supplier selection model for disturbance danger situations and an AHP PROMETHEE fuzzy formula to fight against supplier selection problems. Hosseini and Barker (2016) proposed a business network to measure resilience of a supply chain network in order to choose flexible suppliers based on absorption, comparative, and remedial capabilities. Hosseini et al. (2016a) investigated about a business network model to select suppliers based on resilience.

Primary criteria for selectors

The primary criteria includes some common items utilized during several previous decades in supplier selection such as: cost, quality, leading time, service level, and … . For example, Dickson (1966) introduced 23 criteria for supplier selection still found in current era literature. Kotula et al. (2015) investigated about supplier assessment criteria regarding the viewpoints of the specific beneficiaries in different industries. Hofigtonig et al. (2015) studied on a TOPSIS approach using interval values with importance measurement weights for the selection of suppliers based on confidentiality and keeping capability of the constituents. Memon and et al. (2015) carried research about an integration of a gray system theory and lack of assurance theory to measure supplier criteria such as quality, delivery capability, logistic services, and danger factors. Pitchipo et al. (2015) utilized a gray decision-making model to assess and select suppliers in process industry through which cost, delivery, capacity, and guarantee of the potential suppliers were measured. Saghari and Barrons (2016) introduced and studied the relationship between resilience and supplier's delays as a strategy for demand management in the presence of lack of assurance through an experimental analysis. Mohammaditabar et al. (2016) studied about a theoretical analysis of the play to select suppliers with a limited capacity to analyze selected suppliers and the agreed prices within decentralized supply chains. Panitas et al., (2020) talked about the selection of resilience suppliers in supplying electronic instruments. The chaotic situations are considered as incidents of low probability leading to incomplete evidences to support assessment. Hosseini et al., (2019) dealt with the selection of resilience suppliers and optimal appropriation of orders in the presence of disturbance dangers and claimed that: resilience supplier selection is a key strategic decision regarding supply chain disturbance management and that there would be an efficient resolution to select flexible suppliers and to use optimal order appropriation. Sahebjamnia, N. (2018) studied about resilience supplier selection and order appropriation in uncertainty situations.

Green supplier selection

Green supplier selection is gaining increasing interest among researchers and practitioners due to the growing awareness of environmental protection and its long-term effects on business and marketing issues (Akman et al., 2015). Presently, companies need to consider and include so-called 'green strategies' in order to prevent the negative impact of the industrial processes and also to optimally manage the physical and information flows exchanged between all actors in a supply chain (Gurel, et al., 2015). As a result, the selection of the optimal green supplier is deemed crucial for green supply chain management, which is a challenging multi-dimensional problem. Meanwhile, it may influence the consequences of worse decision-making processes directly and indirectly (Kuo et al., 2010; Konys, 2019).

Developing resilience supplier selection criteria

Resilience supply chain methods have been probed a lot during the last decade. Shafi (2005) has defined resilience in a firm within supply chain as its intrinsic capability to preserve or revive its consistent behavior. Thus, it can continue its usual activities after a destructive incident. Christopher and Pak (2004) emphasized that supply chain resilience can be enhanced regarding the multiple sources of the suppliers, sourcing strategies, changing the suppliers, and commitment to the contracts to supply the materials and help to develop the inventories and upward conditions to have a positive effect on flexibility in supply chain. Meanwhile, Tang (2006) has mentioned the importance of resilience supply basis. Rajesh and Ravi (2015) proposed a gray relationship analysis method to select suppliers regarding the vulnerability, cooperation, risk awareness, and supply chain consistency management to select resilience suppliers. Torabi et al. (2015) developed a two steps random programming model to resolve supplier selection problem and to appropriate resilience. Solfi et al. (2021) introduced resilience supplier selection in complicated products and a subsystem of their supply chain under uncertainty condition and risk disturbances in a case study about satellite parts. Zhang and Zhang (2011) suggested an integrated proper numerical program for supplier selection and random demand purchases. Zhang et al. (2016) investigated about the integration of how the supplier selection can gradually accompany the services and cooperation with customers. Solfio and et al. (2021) studied about resilience supplier selection in complicated products and their supply chain subsystem under uncertainty and risk disorders. M Dio et al. (2020) carried out research on resilience supplier selection in 4.0 logistic and stated that it has been greatly discussed through incongruent data on supplier selection in previous studies. Thoriatanapas et al. (2020) investigated about resilience supplier selection in preparing electronic instruments to integrate observation theory and transformation based on TOPSIS rule to experience complicated incidents which can lead to fights against indefinite and incomplete data. Parmenic et al. (2019) studied about resilience supplier selection. Hosseini et al. (2019) investigated about resilience supplier selection and optimal appropriation in the presence of interference dangers. Çekiç et al., (2022) studied about a managing supplier selection problem with integrated fuzzy AHP and fuzzy VIKOR: A manufacturing company case. Nadir et al., (2020) studied supplier selection using Fuzzy AHP and Fuzzy Vikor for XYZ pharmaceutical manufacturing company. Song et al., (2019) studied about a supplier selection problem based on interval intuitionistic fuzzy multi attribute group decision making. Sahu et al., (2016) investigated about the evaluation and selection of resilient suppliers in a fuzzy environment: Exploration of fuzzy-VIKOR. Rajesh et al., (2018) probed about the selection of suppliers using Swara and Copras-G. Liou et al., (2015) carried out a study on a new hybrid COPRAS-G MADM Model to improve and to select suppliers in green supply chain management. Chatterjee et al., (2018) did research on supplier selection in telecom supply chain management: a fuzzy-rasch based COPRAS- G method. Kayapinar Kaya et al., (2021) was interested in probing an integrated interval type 2 fuzzy AHP and COPRAS-G methodologies for supplier selection in the era of Industry 4.0. Siregar et al., (2019) tried to clarify the priority of suppliers' selection using fuzzy ANP COPRAS-G.

3. MATERIALS AND METHODS

This study is applied in the nature. The data were gathered using a researcher made questionnaire after considering the viewpoints of the scholars and technicians in the field. Considering the research title, Tabriz Compressor Manufacturing Company selected as a case study and in order to identify the relationships and the effects of different factors and their strength a FUZZY DEMATEL method was utilized. Furthermore, in order to compare ranking the suppliers of a company, a fuzzy Vikor and Grey complex proportional assessment (COPRAS-G) method was used through the two questionnaires to collect the required data.

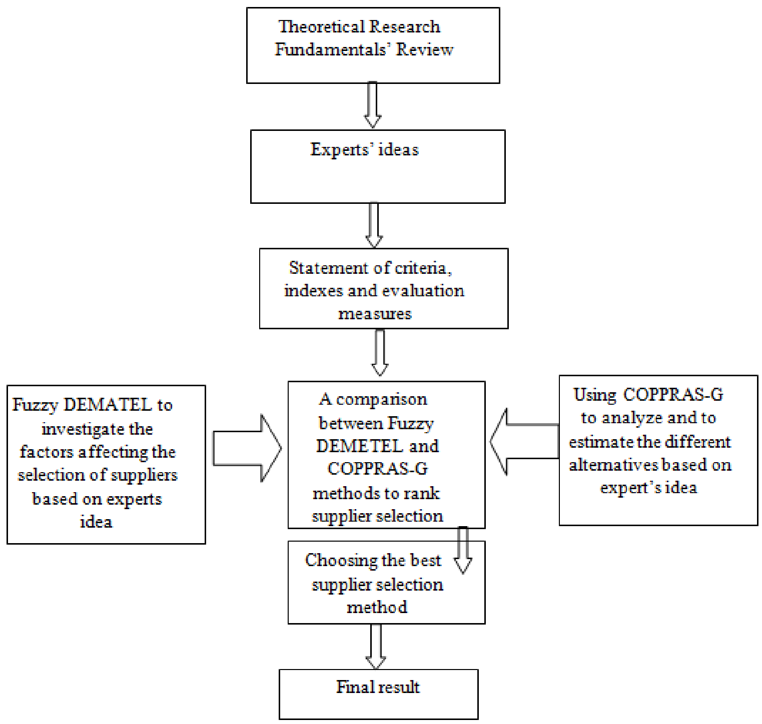

Figure 1. Research Administration Model

In the present research the dimensions of the effect of suppliers' resilience were recognized considering the research literature based on Table 1.

Table 1. Resilience criteria regarding the selection of suppliers

Index name	Selection issues	References
Traditional criteria	Cost, quality, delivery time, responsiveness rate	Hosseini Barker (2016b)
Green criteria	Transportation states compatible with environment, packing and management	Hosseini Barker (2016b)
Resilient supplier selection and optimal order allocation under disruption risks	probabilistic graphical model, stochastic bi-objective mixed integer programming model,	Hosseini et al. (2019)
The qualitative model of supplier selection	Faithfulness, environment, accessibility, CSR, environment, danger factor, suppliers' characteristics, resilience, awareness of novel technology	Singh (2014)
The selection of suppliers regarding beneficiaries' viewpoints	Quality, management of relations with suppliers and profits	Kotula et al. (2015)
Suppliers	Cost, quality, services, delivery, unified innovation	Fazlollah Tabar and Karan (2011)

Selection of suppliers	Reliability and maintainability of parts	Hofigton (2015)
Supplier criteria	Quality, delivering capability, logistic services, dangers to works	Memon et al. (2015)
Selection of suppliers	Cost, delivery, capacity, guarantee of potential suppliers	Pitchipo et al. (2015)
Selection of green suppliers using 5 major criteria	Quality, financial, organization, technology and service capability	Lee et al. (2009)
Selection of green suppliers	Production of pollution, consumption of resources, management commitments	Hashemi et al. (2015)
Green criterion	Financial issues, delivery, services, organizational performance	Huang et al. (2007)
Green suppliers	Green planning, avoiding pollution, green image, green capability, unified environmental management	Akman et al. (2015)
Non-linear multiple purpose optimization to select green suppliers	Transportation, cost, delivery rate, transportation time, service level	Zhang et al. (2013)
Analysis of gray relationships to select suppliers	Vulnerability, cooperation, risk awareness, permanent supply chain management to select resilience suppliers	Rajesh et al. (2015)
Supplier selection and resilience appropriation	Operational risks, interference, supplier business permanence, surplus inventory to strengthen suppliers, contracts with supporter suppliers	Torabi et al. (2015)
Managing supplier selection problem	Quality, time, Service, Cost	Çekiç et al., (2022)
Supplier selection problem based on interval intuition	Product price, Product quality and Service	Song et al., (2019)
Supplier selection in pharmaceutical manufacturing	Regulatory Compliance, Price, and Product Variety	Nadir et al., (2020)
evaluation and selection of resilient suppliers in a fuzzy environment	Product quality, Product reliability, product functionality, Extent of customer satisfaction, product price	Sahu. et al., (2016)

After Table 1 provided, they were screened regarding the viewpoints of the scholars in the field and the results were presented in Table 2 as follows:

Table 2. Resilience supplier selection criteria

Index name	Selection issues		References
Traditional criteria	Cost, quality, delivery time, responsiveness rate		Hosseini and Barker (2016b)
Supplier selection regarding the stakeholders' perspectives	Quality, management of relations with suppliers and profits		Kotula et al. (2015)
Selection of suppliers	Confidentiality and keeping capability of the parts		Hofigton (2015)
Supplier criteria	Quality, delivering capability, logistic services, dangers to works		Memon et al. (2015)
Green Supplier selection	Quality, Financial, organization, Technology and service capabilities		Lee et al. (2009)

Regarding the idea of Tomas L. Saati who believes that the number of scholars should not accede 10 people, the firm scholars were considered as the statistical population. Also, the entails production planning managers, industries' engineers, production lines' managers, the preparation managers of firm included in study.

4. RESULTS AND DISCUSSION

Fuzzy DEMATEL method

Fuzzy is used to assess causal relations. This method is used to recognize the imprecise and abstract nature of DEMATEL to measure human judgments. In fuzzy sets theory we utilize range sets instead of real numbers. The linguistic expressions are changed into fuzzy numbers. The suggested method to reveal the relationship between factors and ranking criteria related to the type of relations and the effect of strength degree of each of the criteria are thought to be optimal. Fuzzy is defined as follows:

DEMATEL method analysis

Step 1: Define assessment criteria

Step 2: Select a group of scholars who have enough knowledge and experience in a field to assess the effect of factors using a dual comparison.

Step 3: Define linguistic fuzzy index to fight against ambiguities of human assessments, the linguistic variable of "interference" using a five-level index includes the following items.

Step 4: The index items in group decision makings proposed by Lee (1994) were used and they were as follows: without effect, very little effect, low effect, high effect, very high effect. Fuzzy numbers for these linguistic expressions are represented. The primary fuzzy direct relationship matrix of Zk was developed through the effectiveness relationships of fuzzy couples between the constituents within an n*n matrix regarding the number of scholars. Accordingly, the direct relationship matrix is created in the form of Zk = [zk_{ij}] where Z is an n*n matrix which is not negative. Z_{ij} represents the direct effect of factor i on factor j and when i=j the diagonal elements will be symbolized as follows, for simplicity $Zk_{ij} = 0$.

For simplicity, denote Z^k as

$$z_{ij}^k = (l_{ij}, m_{ij}, u_{ij})$$

$$Z^k = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} [0,0] & \otimes z_{12}^k & \cdots & \otimes z_{1n}^k \\ \otimes z_{21}^k & [0,0] & \cdots & \otimes z_{2n}^k \\ \vdots & \vdots & \vdots & \vdots \\ \otimes z_{n1}^k & \otimes z_{n2}^k & \cdots & [0,0] \end{bmatrix} \quad (1)$$

Step 5: Change the matrix in an overall form. D is calculated using expressions (2) within the normalized fuzzy direct relationship matrix. On the whole, matrix Z could be calculated using the following fuzzy direct relationship.

$$D = \frac{Z^k}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}}, i, j = 1, 2, \ldots, n \quad (2)$$

Step 6: It could be shown that matrix I with identity n * n will be calculated using expression (2), where T is the total matrix relationship. The high and low amounts are calculated in isolation.

$$T = [t_{ij}]_{nxn} \qquad i,j = 1,2,\ldots n$$

$$r_i = \sum_{1 \le j \le n}^{n} t_{ij} \qquad \forall i$$

$$c_j = \sum_{1 \le i \le n}^{n} t_{ij} \qquad \forall j \tag{3}$$

Step 7: The causal diagram of horizontal axis is ri + cj and the vertical axis is (ri - cj).

The horizontal axis "outstanding" refers to the importance level of the factor, while the vertical axis "relationship" represents the effect amount of the positive axis. If ri - cj , the factor in the group is the cause of the effect.

If the group is negative, the factor is in effect group. Causal diagrams can change the complicated relationships of the factors into an understandable structural model and increase awareness to resolve the problem (Sakar et al., 2017).

4.2. Identifying the relationships and how the effects of factors and their strength are measured using Fuzzy DEMATEL

Steps in Fuzzy MEMATEL method

Fuzzy step 1: the formation of direct relationship matrix

To recognize the pattern for relationships between the different elements, factors n of the criteria forms a matrix of n * n. The effect of the element present in each line will be noted for each of z amounts mentioned in the matrix as a fuzzy number. If we utilize more than 10 people's viewpoints method, the scholars should complete the current matrix. Then the simple average viewpoints utilized and the direct relationship matrix will be formed.

$$\boldsymbol{z} = \begin{bmatrix} \mathbf{0} & \cdots & \tilde{\boldsymbol{z}}_{\boldsymbol{n1}} \\ \vdots & \ddots & \vdots \\ \tilde{\boldsymbol{z}}_{\boldsymbol{1n}} & \cdots & \mathbf{0} \end{bmatrix} \tag{4}$$

The following Table represents the direct relationship matrix which is the same as the binary comparisons of the scholars.

Also, in the Table 3 the fuzzy spectrum utilized in the model has been represented.

Table 3. Fuzzy spectrum

Code	Verbal expression	L	M	U
1	Without effect	1	1	1
2	Low effect	2	3	4
3	Average effect	4	5	6
4	High effect	6	7	8
5	Very high effect	8	9	9

Step 2: To normalize Fuzzy direct relationship matrix we use the following equation:

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \quad (5)$$

$$r = max_{\top}(i,j) \; \left\{\max_{i} \sum_{j=1}^{n} u_{ij}, \max_{j} \sum_{i=1}^{n} u_{ij}\right\} \qquad i,j \in \{1,2,3, \ldots, n\} \quad (6)$$

Step 3: Calculating complete fuzzy relationship matrix.

In this step and based on the following equation, the overall fuzzy relationships matrix is formed.

$$\tilde{T} = \lim_{k \to +\infty} \left(\tilde{x}^{1} \oplus \tilde{x}^{2} \oplus \ldots \oplus \tilde{x}^{k}\right) \quad (7)$$

If any element of fuzzy number of the overall relationship's matrix is formed as follows $\tilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij}$ we would have:

$$\left[l''_{ij}\right] = x_{l} \times (I - x_{l})^{-1} \quad (8)$$

$$[m''_{ij}] = x_{m} \times (I - x_{m})^{-1} \quad (9)$$

$$[u''_{ij}] = x_{u} \times (I - x_{u})^{-1} \quad (10)$$

In other words, first the reverse normal matrix is calculated and then we subtract it from matrix I and finally the normal matrix will be multiplied by the resulting matrix.

Step 4: Defuzzification of the amounts of complete relationship matrix

In order to defuzzificated, we have used upper-quick and bell method. The steps for defuzzification of CFCS are as follows:

$$l_{ij}^{n} = \frac{\left(l_{ij}^{t} - \min l_{ij}^{t}\right)}{\Delta_{min}^{max}} \quad (11)$$

$$m_{ij}^{n} = \frac{(m_{ij}^{t} - min\, l_{ij}^{t})}{\Delta_{min}^{max}} \quad (12)$$

$$u_{ij}^{n} = \frac{(u_{ij}^{t} - min\, l_{ij}^{t})}{\Delta_{min}^{max}} \quad (13)$$

In a way that:

$$\Delta_{min}^{max} = \max u_{ij}^{t} - \min l_{ij}^{t} \quad (14)$$

Upper and lower bank amounts of normal amounts are as follows:

$$l_{ij}^{s} = m_{ij}^{n} \Big/ (1 + m_{ij}^{n} - l_{ij}^{n})$$

$$u_{ij}^{s} = u_{ij}^{n} \Big/ (1 + u_{ij}^{n} - l_{ij}^{n})$$

(15)

The resulting algorithm is a cfcs matrix using absolute amounts.

Step 4: Calculating normalized total absolute amounts

$$x_{ij} = \frac{[l_{ij}^{s}(1 - l_{ij}^{s}) + u_{ij}^{s} \times u_{ij}^{s}]}{[1 - l_{ij}^{s} + u_{ij}^{s}]}$$

(16)

Step 5: Threshold level calculations

All amounts of the absolute complete relationships matrix that are less than the average complete relationships matrix was recognized and made equal to zero using the following equation. In other words, that causal relationship is not taken into consideration.

$$U_{ij} = \begin{cases} V_{ij} & V_{ij} \geq TS \\ 0 & Others \end{cases} \quad (17)$$

The Table below represents complete relationships matrix less than the threshold level. The cause-and-effect relationships between the constituents are designed based on the Table 10. In this research, the threshold amount (TS) is equal to 0.3840.384.

Step 6: Final output and creation of causal diagram

The next step is to calculate total amounts of rows and columns of matrix (T). The total amount of columns (D) and rows (R) could be calculated regarding the following formulas.

$$D = \sum_{j=1}^{n} T_{ij}$$

$$R = \sum_{i=1}^{n} \tilde{T}_{ij} \quad (18)$$

Then, regarding R, D, the amounts of D-R and D+R could be calculated and they will represent the amount of interaction and effectiveness power of the factors, respectively.
The final output is represented in the Table 4.

Table 4. Final output

	R	D	D+R	D-R
D1 (cost)	5.351	5.26	10.611	-0.09
D2 (quality)	4.929	5.036	9.965	0.107
D3 (delivery time)	4.8	4.895	9.695	0.095
D4 (response time)	5.015	5.066	10.082	0.051
D5 (parts supply capability)	4.823	4.758	9.582	-0.065
D6 (profit)	4.901	4.91	9.812	0.009
D7 (supplier capability)	5.369	5.334	10.703	-0.035
D8 (reliability of parts)	4.801	4.846	9.647	0.046
D9 (delivery capability)	5.218	5.151	10.37	-0.067
D10 (logistic services)	5.28	5.231	10.511	-0.049
D11 (finical)	4.659	4.619	9.277	-0.04
D12 (Organization)	4.769	4.776	9.545	0.008
D13 (Technology and service capabilities)	4.95	4.981	9.932	0.031

The Figure 2 diagram represents meaningful relations. This pattern is in the form of a diagram through which the vertical axis amounts of D + R, and the horizontal axis amounts of D – R are identified. The status and relationships between each factor and a point with coordinates of (D-R, D+R) are determined through the pattern below.

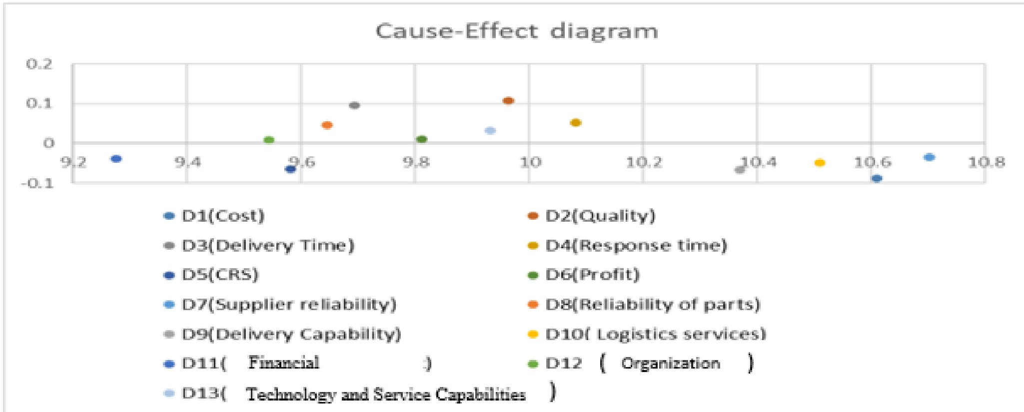

Figure 2. Relationships pattern diagram

Step 7: Results interpretation

Regarding the diagram and the Table above, each factor is investigated regarding four dimensions.
The amount of effectiveness of variables: The total sum of each line (D) for any factor represents the amount of its effectiveness on other factors in the system. In the present study, (cost) D1 has the highest effectiveness and (quality) D2, (delivery time) D3, (response time) D4, (parts supply capability) D5, (profit) D6, (supplier reliability) D7, (reliability of parts) D8, (delivery capability) D9, (logistics services) D10, (Risk factors to work) D11, (Capacity) D12, (potential suppliers guarantee) D13 are ranked next.

The variables being affected amount: The total sum of each column (R) for each factor represents the amount they are being affected by other system factors. In the present study (supplier reliability) D7 has the highest capability of being affected, and (cost) D1, (logistics services) D10, (delivery capability) D9, (response time) D4, (potential suppliers guarantee) D13, (quality) D2, (profit) D6, (parts supply capability) D5, (reliability of parts) D8, (delivery time) D3, (Capacity) D12, and (Risk factors to work) D11 rank next.

The horizontal vector (D + R) represents the number of effects and counter effects of the intended factor in the system. In other words, the higher amount of D + R means higher interaction of that factor with other factors in the system. In the present study, (supplier reliability) D7 has the highest capability of being effective and (cost) D1, (logistics services) D10, (delivery capability) D9, (response time) D4, (quality) D2, (potential suppliers guarantee) D13, (profit) D6, (delivery time) D3, (reliability of parts) D8, (parts supply capability) D5, (Capacity) D12, and (Risk factors to work) D11 rank next.

The vertical vector (D-R) represents the power to be affected by any factor. On the whole, if (D-R) is positive, the variable is considered as a cause variable and if it is negative, it is considered as an effect. In the present research (quality) D2, (delivery time) D3, (response time) D4, (profit) D6, (reliability of parts) D8, (Capacity) D12, and (potential suppliers guarantee) D13 are cause and (cost) D1, (parts supply capability) D5, (supplier reliability) D7, (delivery capability) D9, (logistics services) D10, and (Risk factors to work) D11 are considered as the effect.

4-3- Fuzzy VIKOR method to rank suppliers

To rank suppliers in following subsections, Fuzzy VIKOR method has been utilized and presented.

Fuzzy MCDM: In classic MCDM, the assessment of alternatives and weights is done precisely and clearly and depends on researcher's attention. Usually, the assessment of important alternatives and weights of the criteria cannot be done reliably. In this case, it may result from different sources such as those data which cannot be involved qualitatively, imprecisely, and unreliably regarding the controversies within the selection process (Chen and et al., 2009). In such a case, Fuzzy sets theory proposed by Bellman and et al. (1970) is introduced to model intrinsic unreliability in human judgments towards MCDM and is known as Fuzzy MCDM. Within Fuzzy MCDM, performance assessment and weighing is represented using Fuzzy numbers. Leo and et al. (2012) stated that triangular fuzzy numbers and trapezoid fuzzy numbers (TzFN) have the highest usage in theory and practice regarding fuzzy numbers. In fact, triangular fuzzy number is considered as a specific case of TzFN. When the two average amounts are the same, TzFN is changed into triangular fuzzy numbers. For simplicity and without loss of the totality, TzFN prefers the reflection of linguistic variables in the present study. For example, positive TzFN of A using the symbol x1=2, x3=3, x3=5, x4=6(has been represented in figure 3.

Figuer. 3. Trapezoid fuzzy numbers

Regarding both (b1, b2, b3, b4) = $\tilde{\tilde{\boldsymbol{B}}}$ and TzFN Ã= (a1, a2, a3, a4), positive amounts and positive real numbers of r, algebraic operations of TzFN can be stated as follows:

$$\tilde{A} \oplus \tilde{B} = [a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4], \quad \tilde{A} \Theta \tilde{B} = [a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1],$$
$$\tilde{A} \otimes \tilde{B} \cong [a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4], \qquad r \otimes \tilde{B} \cong [rb_1, rb_2, rb_3, rb_4]. \quad (19)$$

The linguistic variable is the one whose amount is determined in a non-numerical and in the form of words. The concept of language variables is very useful regarding situations with high complexity or difficulty stated in a qualitative expression.

The linguistic values represented in fuzzy numbers (Zadeh Al, 1987) represent a level of specialty which is more appropriate with the use of fuzzy linguistic variables.

Multiple criteria optimization methods and negotiation resolution or multiple criteria optimizations of VIKOR is developed within a complicated system. The negotiation method determines the best resolution from among a set of options. The negotiation resolution compares the closeness degree to the ideal alternative. Every alternative can be assessed using any criterion function

A systematic approach uses Fuzzy VIKOR method for several criteria within fuzzy environment. Based on ideas posed by Zhang and et al. (2005), the goal of this approach is to find the best resolution between the decision makers for adjustment with human cognitive goals. VIKOR algorithm based on revised fuzzy numbers are as follows:

Step 1: statement of the multiple criteria decision-making problem in the form of a matrix

There are m options that can be defined as (Ai = 1, 2, …, m) chosen based on the selected criterion where Cj = (1, 2, …, n). Abstract assessment is done to identify decision making matrix. Using the linguistic variables, they are identified.
The decision matrix can be stated as follows:

$$X = \begin{matrix} & C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix}, \; i = 1, 2, \ldots, m \,; j = 1, 2, \ldots, n$$

$$W = [w_1, w_2, \ldots, w_n] \qquad (20)$$

Where (A1, A2, A3, …, Am) are options that should be selected. (C1, C2, C3, …, Cn) are assessment criteria. Xij is ranking the option Ai regarding Cj. Wj represents importance weight of the jth criterion.
Step 2: Make a fuzzy decision matrix

The fuzzy sum of ranking (Zaghami, 2008) is gained through the correction of trapezoid fuzzy numbers regarding the mathematical weight mean (Hesabi and et al., 2009) and it could be calculated using the following equation:

$$\tilde{X} = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{g=1}^{5} x_{ijg} \otimes TzFN = [\tilde{X}_{ij}]_{m\times n} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]$$

$$\tilde{X} = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{g=1}^{5} x_{ijg} \otimes TzFN = [\tilde{X}_{ij}]_{m\times n} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}$$

$$\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n]$$

$$\tilde{x}_{ij} = (\tilde{a}_{ij}, \tilde{b}_{ij}, \tilde{c}_{ij}, \tilde{d}_{ij}). \qquad (21)$$

Step 3: Assess criteria fuzzy importance weight.

Fuzzy weight amounts for each criterion is determined based on importance of any criterion. The relative value is directly proportionate with the number of production lines for certain issue (Mosaee and et al., 2013).

$$\tilde{w}_j = \tilde{s}_j \Big/ \sum_{j=1}^{n} \tilde{s}_j$$

(22)

S is the amount of standard deviation for the criterion: Cn is criterion deviation and Sij is represented as follows:

$$\tilde{s}_j = \sqrt{\frac{1}{M}\sum_{m=1}^{M}\left(\tilde{x}_{mn} - \bar{\tilde{x}}_n\right)^2}$$

(23)

Also,

$$\bar{\tilde{x}}_n = \frac{1}{M}\sum_{m=1}^{M}\tilde{x}_{mn} \;,\; 0 \le \tilde{w}_j \le 1$$

(24)

And M = T is known as the total options.

Step 4: Determine the best fuzzy amount $\tilde{x}j*$ and the worst fuzzy amount $\tilde{x}j$.

$$\tilde{x}_j^* = \max_i \tilde{x}_{ij} \,,$$
$$\tilde{x}_j^- = \min_i \tilde{x}_{ij} \,.$$

(25)

Step 5: Calculate normalized fuzzy decision-making matrix.

The normalized fuzzy decision matrix is calculated to make sure of the value of any criterion between 0 and 1 in a way that all criteria are standardized and comparable with each other. In this case, VIKOR method uses linear normalization for stabilization (Opricowich, 2004). The linear normalization formula with Si and Ri is represented as follows:

$$\tilde{S}_i = \sum_{j=1}^{n}\tilde{w}_j\left(\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{\tilde{x}_j^* - \tilde{x}_j^-}\right) \quad \text{and} \quad \tilde{R}_i = \underset{j}{Max}\left[\tilde{w}_j\left(\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{\tilde{x}_j^* - \tilde{x}_j^-}\right)\right]$$

(26)

Step 6: Calculate VIKOR Q I index.

$$\tilde{Q}_i = v\left(\frac{\tilde{S}_i - \tilde{S}^-}{\tilde{S}^+ - \tilde{S}^-}\right) + (1-v)\left(\frac{\tilde{R}_i - \tilde{R}^-}{\tilde{R}^+ - \tilde{R}^-}\right)$$

$$\text{where} \quad \begin{aligned} \tilde{S}^+ &= \max_i \tilde{S}_i , \tilde{S}^- = \min_i \tilde{S}_i \\ R^+ &= \max_i \tilde{R}_i , \tilde{R}^- = \min_i \tilde{R}_i \end{aligned}$$

(27)

V is introduced as the weight in maximum optimized strategy. It could be inferred from the amount of Vikor that the amount is normally considered as v=0.5.

Step 7: Arrange the values in a descending order of S˜ ،R˜ and Q˜

The best alternatives were Q˜of the highest possible amount for Q˜based on merit score which was the symbol A (1) in the present study. The second big alternative was A (2) and the least amount for Q˜was

called Am. The options A(1) located in the best part with the maximum amount of Q̃ is known as the best alternative in presenting the adjustment resolution if and only if there exist two conditions.
The best alternative in proposing a method of Q̃ located in the best position called A (1) is suggested if and only if there exist two conditions.

C1: Acceptable advantage

The amounts greater than (2) or equal to A or A (1) regarding the option VIKOR Q̃ are known as the difference index of A (1), or as the best advantage is known as DQ (2).

$$\tilde{Q}_{(A^{(2)})} - \tilde{Q}_{(A^{(1)})} \geq DQ \text{ with } DQ = \frac{1}{M-1} \quad (28)$$

C2: Acceptable consistency in decision making

R̃ or S̃ should be in the best ranking by A (1) (Mosaee and et al., 2015). In this research there are 13 criteria and 13 options that are ranked based on Fuzzy VIKOR method. These criteria are selected based on the viewpoints of the scholars in Compressor Manufacturing Company in Tabriz and the characteristics of the criteria are represented in the following table.

First Step: The statement of multiple criteria decision-making problem in the form of a matrix
Second Step: Fuzzy decision-making matrix

The following table represents fuzzy decision-making matrix. If the ideas of several scholars are used in assessment, the following matrix will represent the mathematical mean of the whole scholars.
Third Step: Fuzzy importance weight

Fourth Step: Identifying positive and negative ideals

The positive and negative ideals of any criterion could be identified regarding the following equations.
If the criterion amount is positive, there would be positive ideal ($\tilde{f}^*$), and the negative ideal $(\tilde{f}^\circ)$ will be calculated as follows:

$$\tilde{f}_j^* = \underset{i}{Max}\, \tilde{f}_{ij} \qquad i=1,2,\ldots,n$$
$$\tilde{f}_j^\circ = \underset{i}{Min}\, \tilde{f}_{ij} \qquad i=1,2,\ldots,n \quad (29)$$

If the criterion amount is negative, there would be positive ideal ($\tilde{f}^*$), and the negative ideal $(\tilde{f}^\circ)$ will be calculated as follows:

The amount of Q could be calculated using the following equation:

$$\tilde{f}_j^* = \underset{i}{Min}\, \tilde{f}_{ij} \qquad i=1,2,\ldots,n$$
$$\tilde{f}_j^\circ = \underset{i}{Max}\, \tilde{f}_{ij} \qquad i=1,2,\ldots,n \quad (30)$$

The following table represents the positive and negative ideal amounts.
Sixth Step: VIKOR index
If

$$\tilde{Q}_i = (Q_i^l, Q_i^m, Q_i^r)$$

$$\widetilde{\mathbf{Q}}_{\mathbf{i}} = \boldsymbol{v}\frac{(\tilde{\boldsymbol{s}}_{\boldsymbol{i}} \ominus \tilde{\boldsymbol{s}}^{*})}{\boldsymbol{s}^{\circ r} - \boldsymbol{s}^{*l}} \oplus (\mathbf{1} - \boldsymbol{v})\frac{(\widetilde{\boldsymbol{R}}_{\boldsymbol{i}} \ominus \widetilde{\boldsymbol{R}}^{*})}{\boldsymbol{R}^{\circ r} - \boldsymbol{R}^{*l}} \tag{31}$$

Where,

$$\tilde{\boldsymbol{s}}^{*} = \min_{i} \tilde{\boldsymbol{s}}_{\boldsymbol{i}}$$
$$\boldsymbol{s}^{\circ r} = \max_{i} \ \boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{r}}$$
$$\widetilde{\boldsymbol{R}}^{*} = \min_{i} \widetilde{\boldsymbol{R}}_{\boldsymbol{i}}$$
$$\boldsymbol{R}^{\circ r} = \max_{i} \ \boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{r}} \tag{32}$$

The changing variable V that shows the maximum optimal point in the group is equal to 0.5 in thresent study the fuzzy values of S˜i, R˜i and Q are deceived according to the below formula:
If A˜= (l, m, u). (A˜ is a fuzzy number).

$$Crisp(\tilde{A}) = \frac{2m + l + u}{4} \tag{33}$$

Seventh Step: Determine amounts of S˜i and R˜i

In this step, first we should weigh the normal matrix and then calculate the amounts using the following equations. .If

$$\tilde{\mathbf{s}}_{\mathbf{i}} = (\boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{l}}، \boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{m}}، \boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{r}}) \text{ و } \widetilde{\boldsymbol{R}}_{\mathbf{i}} = (\boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{l}}، \boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{m}}، \boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{r}}) \tag{34}$$

$$\tilde{S}_i = \sum_{j=1}^{J} (\tilde{w}_j \otimes \tilde{d}_{ij}) \,/$$
$$\tilde{R}_i = \max_{j}(\tilde{w}_j \otimes \tilde{d}_{ij}) \tag{35}$$

Seventh Step: Determine amountand R˜i

In this step, first we should weigh the normal matrix and then calculate the amounts using the following equations.

If $$\tilde{\mathbf{s}}_{\mathbf{i}} = (\boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{l}}، \boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{m}}، \boldsymbol{s}_{\boldsymbol{i}}^{\boldsymbol{r}}) \text{ و } \widetilde{\boldsymbol{R}}_{\mathbf{i}} = (\boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{l}}، \boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{m}}، \boldsymbol{R}_{\boldsymbol{i}}^{\boldsymbol{r}}) \tag{36}$$

Seventh Step: Arrange the values in a descending order of S˜ ،R˜ and Q˜

We defuzzificated the values and use them regarding the equations S˜i and R˜i in ranking.

Table 5. The absolute amounts of S˜ ،R˜ and Q and options' rank

Definitive values / Rank	S˜	Rank	R˜	Rank	Q	Rank	
A1	0.1	11	0.03	2	0.017	1	
A2	0.119	8	0.03	3	0.024	2	
A3	0.23	13	0.027	1	0.05	3	
A4	0.38	10	0.041	5	0.17	5	
A5	0.374	9	0.04	4	0165	4	

In this step and regarding S̃ ،R̃ and Q̃ related to the options arranged in a descending order would be decided on. For value determination two conditions should be met and based on these two prerequisites, three states would result and based on them the decisions are made.

Condition 1: Acceptable advantage
A is determined based on the amounts of the first and second options based on the amount of Q, and n represents the number of options. If A (1) and (2)

$$Q(A(2)) - Q(A(1)) \geq 1/n - 1 \quad (37)$$

Condition 2: Acceptable consistency in decision making
The option A (1) should at least be known as a superior rank in one of R or S groups. The states occurred is:
When the first condition is not met, a set of options could be selected as the superior options.
State 1:
Superior options: $= A(1) ، A(2) ، \ldots ، A(M)$
The highest amount of M is calculated regarding the following equation.

$$Q\big(A(M)\big) - Q\left(A\,(1)\right) < 1/n - 1 \quad (38)$$

State 2:
When only the second condition is not met, two options A (1) and (2) are selected as the superior options.
State 3:
If both conditions are met, the option with the least Q will be selected as the best option. The amount of acceptance of the conditions is represented in the following table.

Table 6. Acceptance of conditions

First Condition	Not accepted
Second Condition	-
The selected state	First state

Therefore, alternative 1, alternative 2, alternative 3, alternative 4, and alternative 5 are selected as the final alternatives.

COPRAS-G

To accommodate the incomplete data in the decision makers' judgments, a grey system theory is applied to convert the crisp values (white numbers) into the grey numbers, which plays an important role in the real-time MCDM process. The grey relational grade model is very effective to handle discrete data. Therefore, the decision makers' judgments, which accommodate an uncertain level of information, can be described using the grey system through the classification of white, black and grey numbers (Maity et al., 2012).

COPRAS-G is a newly developed approach within the MCDM process to evaluate the alternatives, in which values of the attributes are expressed in an interval format. It is completely logical and useful mathematics to process incomplete information about the system and is intended to increase the efficiency and to improve the accuracy level of the resolution through the decision-making process.

The COPRAS-G approach is used to analyze the different alternatives, and to estimate the alternatives according to their significance and degree of utility. The degree of utility of an alternative is shown as a percentage. The percentage illustrates the degree to which one alternative is considered to be as a better or worse alternative than the other ones. It estimates the market value of alternatives and gathers diverse recommendations. Other MCDM approaches do not have such features and therefore COPRAS-G altered it within the decision-making process. COPRAS-G supports the decision makers to make more accurate decisions. COPRAS-G is approved due to effectively handling the problems of dealing with uncertainty, subjectivity, and imprecise data (Nguyen et al., 2014).

The procedural steps of COPRAS-G method are presented as follows (Maity et al., 2012; Bitarafan et al., 2012):

Step 1: For a decision-making problem, select a set of the most important criteria, describing the alternatives.
Step 2: Develop the decision matrix ⊗X, where the criteria values are expressed in intervals.

$$\otimes X = \begin{bmatrix} \otimes x_{11} \otimes x_{12} & \cdots & \otimes x_{1n} \\ \vdots & \ddots & \vdots \\ \otimes x_{1n} \otimes x_{12} & \cdots & \otimes x_{1n} \end{bmatrix} = \begin{bmatrix} [x_{11}, b_{11}][x_{12}, b_{12}] & \cdots & [x_{1n}, b_{1n}] \\ \vdots & \ddots & \vdots \\ [x_{m1}, b_{m1}][x_{m2}, b_{m2}] & \cdots & [x_{mn}, b_{mn}] \end{bmatrix} \quad (39)$$

Where ⊗ xij is the interval performance value of ith alternative with respect to jth criterion. The value of ⊗xij is determined by xij (the smallest value or lower limit) and bij (the highest value or upper limit).

Step 3: Normalize the decision matrix,⊗ X using the following equations. Equation (19) is used for xij or lower limit values, whereas, equation (20) is applied for bij or upper limit values.

$$\otimes \overline{X} = [\overline{x}_{ij}]_{m\times n} = \frac{2x_{ij}}{\left[\sum_{j=1}^{n} x_{ij} + \sum_{j=1}^{n} b_{ij}\right]} \quad (40)$$

$$\otimes \overline{X} = [\overline{b}_{ij}]_{m\times n} = \frac{2b_{ij}}{\left[\sum_{j=1}^{n} x_{ij} + \sum_{j=1}^{n} b_{ij}\right]} \quad (41)$$

Step 4: Calculate the weights (relative importance) of the considered criteria.

Step 5: Determine the weighted normalized decision matrix⊗X, using the following equations:

$$\otimes \overline{\overline{X}} = [\overline{\overline{x}}_{ij}]_{m\times n} = \overline{x}_{ij} \times w_j$$
$$(i = 1, 2 \ldots, m;\ j = 1, 2, \ldots, n) \quad (42)$$

$$\otimes \overline{\overline{X}} = [\overline{\overline{b}}_{ij}]_{m\times n} = \overline{b}_{ij} \times w_j \quad (43)$$

Where wj is the weight of jth criterion.

Step 6: Calculate the weighted mean normalized sums for both the beneficial criteria and non-beneficial criteria for all the alternatives.

$$p_i = \frac{1}{2}\sum_{j=1}^{k}\left(\overline{\overline{x}}_{ij} + \overline{\overline{b}}_{ij}\right) \quad (44)$$

$$R_i = \frac{1}{2}\sum_{j=k+1}^{n}\left(\overline{\overline{x}}_{ij} + \overline{\overline{b}}_{ij}\right) \quad (45)$$

Where Pi and Ri are the weighted mean normalized sums for the beneficial and non-beneficial criteria regarding ith alternative, and k is the number of beneficial criteria.

Step 7 : Determining the minimum value of Ri

$$R_{\min} = \min R_i (i = 1, 2, \ldots, m) \quad (46)$$

Step 8 Calculate the relative significances (priorities) of the alternatives.

The priorities of the candidate alternatives are calculated based on Qi values. The greater the value of Qi, the higher is the priority of the alternative. The relative significance of an alternative shows the degree of satisfaction attained by that alternative. The alternative with the highest relative significance value (Qmax) is the best choice among the feasible candidates. The relative significance (Qi) of ith alternative is obtained as follows:

$$Q_i = P_i + \frac{R_{\min} \sum_{i=1}^{m} R_i}{R_i \sum_{i=1}^{m} (R_{\min} / R_i)} = P_i + \frac{\sum_{i=1}^{m} R_i}{R_i \sum_{i=1}^{m} (1/R_i)} \quad (47)$$

Step 9: Determine the maximum relative significance value.

$$Q_{\max} = \max Q_i (i = 1, 2, \ldots, m) \quad (48)$$

Step 10 Calculate the quantitative utility (Ui) for ith alternative.

The degree of an alternative's utility is directly associated with its relative significance value (Qi). The degree of an alternative's utility, which leads to a complete ranking of the candidate alternatives, is determined by comparing the priorities of all the alternatives using the most efficient one and is expressed as follows:

$$U_i = \left[\frac{Q_i}{Q_{\max}} \right] \times 100\% \quad (49)$$

These quantitative utility values of the alternatives range from 0% to 100%. Thus, COPRAS-G method allows the evaluation of the direct and proportional dependence of significance and utility degrees of the intended alternatives in a decision-making problem involving multiple criteria, their weights and performance values of the alternatives regarding all the criteria.

Table 7. Weighted normalized matrix

Alternatives	Pi	Ri	1/R	Qi	Ui		Ranking
A1	0.0871	0.0147	67.90	0.0965	89.154	89.154	3
A2	0.0751	0.0094	106.87	0.0897	82.949	82.949	5
A3	0.0866	0.0098	102.14	0.1006	92.968	92.968	2
A4	0.0790	0.0100	99.50	0.0927	85.663	85.663	4
A5	0.0916	0.0147	67.90	0.1009	93.260	93.260	1

The initial decision matrix was then normalized. The weighted decision matrix $\otimes\bar{\bar{X}}$ presented in Table 14 was constructed next. We then followed the procedure described earlier and determined the relative significance of each alternative by calculating Pi using equation (43), Ri using equation (44), and Qi using equation (46). Following this step, we determined the utility degree of each alternative (Ui) using equation (48). Table 24 presents the Pi Ri, Qi, and Ui for the five suppliers under consideration. According to the table 24 shows that the green supplier selection A (5) in the first rank, selection of suppliers (3), the traditional criteria A (1), supplier selection (4), supplier selection from the stockholder's perspective A (2), the second, third, fourth and five ranks respectively.

Table 8. Compare of Fuzzy Dimetal and COPPRAS-G Methods

Alternatives	A1	A2	A3	A4	A5
Name of model	Ranking				
Fuzzy Vikor	1	2	3	5	4
COPRAS-G	3	5	2	4	1

COPRAS-G is known as a novel developed approach within MCDM processes to measure alternative options through which features' amounts are expressed within a range. Mathematically it would be logical and useful to process the system's incomplete data. Also, the isolation process has been utilized within the decision-making process to increase efficacy and to improve the precision level. Furthermore, to accommodate incomplete data within decision makers' judgments, a grey system theory has been utilized to change the absolute amounts (white numbers) into grey numbers which has an outstanding role within MCDM processes.

According to table 25, it could be observed that COPRRAS-G method is a useful one since Fuzzy VIKOR utilizes a grey system theory in order to change absolute amounts (white numbers) into grey numbers. This has a vital role in suppliers' ranking process decision making in Compressorsazi firm in Tabriz. This is due to the fact that it is a developed novel approach of MCDM to measure the alternatives. Regarding the comparison of these two methods in the table above, the COPRRAS-G method presents a better method in ranking the suppliers within Tabriz Compressor Manufacturing Company because in this method the very first element in supplier's ranking recommends the green suppliers for the company. This factor plays a considerable role regarding all industrial companies. Also, compatibility with the environment is proposed using this method within the whole industrial companies to manufacture products compatible with the environment.

5. CONCLUSION

Regarding the data analysis, the results of the present research can answer the research questions as follows:What are the effective factors on flexibility to select and rank the suppliers?.To answer the research question, first we considered the viewpoints of the industry scholars on effective factors in selection and ranking the suppliers to identify the relationships and define how the factors were effective and to what extent did they affect using a fuzzy DEMATEL method and the following results were obtained: In the present study, (cost) D_1 has the highest effectiveness and (quality) D_2, (delivery time) D_3, (response time) D_4, (parts supply capability) D_5, (profit) D_6, (supplier reliability) D_7, (reliability of parts) D_8, (delivery capability) D_9, (logistics services) D_{10}, (Risk factors to work) D_{11}, (Capacity) D_{12}, (potential suppliers guarantee) D_{13} ranked next. Also (supplier reliability) D_7 has the highest capability of being effective and (cost) D_1, (logistics services) D_{10}, (delivery capability) D_9, (response time) D_4, (quality) D_2, (potential suppliers guarantee) D_{13}, (profit) D_6, (delivery time) D_3, (reliability of parts) D_8, (parts supply capability) D_5, (Capacity) D_{12}, and (Risk factors to work) D_{11} ranked next.Therefore, regarding the results obtained, it would be necessary to pay much attention to the cost criterion (D_1) because it is much more affected than other criteria. This company should control the costs of suppliers and through applying more control on suppliers, creating proper relations with the suppliers, cooperating with the suppliers to supply the raw materials and parts in time, creating several looped networks of the suppliers to alter next suppliers using these loops in order to control the costs. On the other hand, regarding the quality (D_2) located in the second rank of being affected compared to other criteria, it can try to receive parts and raw materials with high quality. The firm can make parts quality trend better to receive from the suppliers in order to increase the efficiency of the company. Thus, regarding the results of the present research and considering the results of a research by Karimi (2016), about the selection of suppliers within flexible supply chain in a case study on SAPCO firm using fuzzy DEMATEL, better and more appropriate decision-making results were achieved in the current study.What are importance degrees of effective factors in resilience to select and rank the suppliers?, To respond to this question, we have used a COPRAS-**G** method to identify the importance degrees of the selection and ranking the suppliers regarding the viewpoints of the scholars in industry and the results were as follows: Due to the results gained in the present study and considering table 24, it could be observed that the green supplier selection (A_5) in resileance to select and rank the suppliers ranked the first, the supplier's section (A_3) ranked the second, traditional criteria (A_1) ranked the third, suppler criteria (A_4) gained the fourth rank, and supplier selection from the stakeholders' perspectives (A_2) scored fifth, respectively. This means that green supplier selection is deemed highly important in Compressor Manufacturing Company in Tabriz. This is due to the fact that selecting the optimal green supplier is considered as a crucial step in green supply chain management, which is a challenging multi-dimensional problem. Meanwhile, it may influence the sequences of worse decision-making processes both directly and indirectly. A suitable green suppliers' recommendation forms the basis for a successful building of a competitive advantage of a company. The selection of green suppliers arises from a company's inclination to respond to any existing trend in environment to respond to any existing trends in an environment. On the other hand, the second rank is attributed to the raw materials' delivery time prepared by the suppliers for the company. The choice of a company regarding valuable suppliers ought to be focused on the type of partners that aim to respect green practices and technologies to increase sustainability.

Also, to calculate table 15, it could be observed that the selection of suppliers (A_3) ranked the second. This means that Reliability and maintainability of parts is deemed highly important in Compressor Manufacturing Company in Tabriz. The maintenance supplier selection and order allocation models aim to assist the decision-maker in choosing the best maintenance suppliers and determining the quantity order of each part. Furthermore, maintenance strategy selection plays a significant role in the reliability and maintenance parts in supplier selection process. The applied maintenance strategy may affect several factors in manufacturing systems, such as demand for parts, system reliability, and total costs. So, it is essential to select the proper maintenance strategy and supplier selection process to have a successful system. Moreover, it forms long term-relationship, a significant commitment of the supplier to maintain equipment, and to achieve lower wholesale prices. Regarding the results gained from the present study and considering the results of a research carried out Kayapinar Kaya et al., (2021) an integrated interval type 2 fuzzy AHP and COPRAS-G methodologies for supplier selection in the era of Industry 4.0 would lead to better results. Considering the results gained from the present study, the following suggestions could be proposed to company: It would be better to use Pull/Push policy regarding the suppliers because through the exploitation of such a policy, it can establish better relationships with the suppliers and can supply the parts more easily. It would be better for the company to highly value logistics services on the part of the suppliers because presenting better logistics services on the part of the suppliers will lead to receive parts in appropriate time and to avoid costs resulting from lack of in time delivery of the parts and lost opportunity costs. Considering the quality of the firm suppliers, it should value the quality of parts supplied and raw materials received from the suppliers highly. This would regard the demanded items on the part of the firm towards the suppliers and in the same way it would affect supply of parts by the suppliers. On the contrary, if there exists a violation of the requested quality of the firm, the machines will be worn out repeatedly and the production lines will stop to work well.

Regarding the response and delivery capability of the suppliers, the firm should create proper communication channels to make the suppliers responsive in time. To do so, the firm should create connection loops in parts and raw materials delivery capability when there exists a contradiction about the current state and the suppliers' promise to hold regular meetings with the suppliers and to emphasize the type of raw materials and parts demands according to the requests on the part of the firm. In this way the firm can make the suppliers more responsive and also receive the remedial sums of money for the losses incurred when there exists a contradiction in the delivery of raw materials and parts. Regarding the response and green supplier selection, the threat of increasing greenhouse gas emissions has caused some governments to impose stricter regulations and standards. These requirements, as well as environmental awareness among industry decision makers, have led to green considerations in doing business, including supplier selection. Therefore, in order to choose a green supplier, the company should consider the basic criteria of cost, quality and technology, and the green criteria of pollution production, resource consumption, and management obligations.

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