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Towards 'gresilient' supply chain management: A quantitative study

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ABSTRACT

The vast majority of current literature handle supplier selection problem considering green and resilience aspects, bifurcately. But green supply chain performance is subject to disruption by internal /or external events. This initiates the need for a merged management approach to establish green and resilient supply chains, that we hereby present it as "gresilient" supply chain management. At the institutional level, the integration of measures of these two paradigms into supply chain processes frets substantial management challenges. This research intends to overcome some of these challenges in exploring, identifying and quantifying resiliency and greenness performance in supplier selection context. To this end, this work aims to: (1) explore and analyse the need and complementarities for or between resiliency and greenness in supply chain context; (2) identify the criteria of greenness and resiliency (a new framework for resilient supplier was developed in considering criteria of development, agility, robustness, sensing and flexibility (DARSF) into a unified framework; (3) quantify the gresilience performance measures by proposing a quantitative approach to evaluate the relative importance of the 'gresilience' criteria and suppliers' gresilience performance via multi-criteria decision making (MCDM) algorithms. The main findings are: (i) a holistic gresilient supplier evaluation framework; and (ii) a user-friendly decision-making tool to gauge gresilience performance of suppliers. This research provides them with a clear insight towards gresilient advantages in today' highly competitive business. This research bridges the literature gap in addressing the supplier selection problem from resiliency and greenness perspectives, jointly.

1. Introduction

In the last two decades, the business has experienced several developments and changes that make firms increasingly encounter new challenges such as globalization. Hence, the market is becoming highly challenging and competitive, and thus modern supply chain management should be accomplished to adopt these changes. Supplier assessment/selection is a vital decision among the activities of supply chain management (Damert et al., 2018 and Tseng et al., 2019). Where enterprises have become highly willing to improve sourcing in attaining a pool of robust suppliers towards a competitive industry. This is relied on the fact that purchasing dominates a share of 40 %–70% out of total cost, and so it has a significant impact on the price and superiority of products (Dyer and Singh, 1998).

In the supplier selection process, decision makers (in the purchasing team) find, assess, select and contract suppliers. As mentioned previously, this process poses a significant share (i.e., an average of 55%) of an organization's financial assets. Organizations hereby seek benefits in signing with suppliers to present high performance in return. Arguably, the core of this activity is based on supplier performance measures that is normally determined vis-à-vis several criteria; further details on supplier assessment process is presented in Section 2.4. Traditionally, purchasing costs, products quality and lead time are among the most popular criteria in supplier assessment (Chai and Ngai, 2020; Guarnieri and Trojan, 2019; Mohammed, 2019 and Ho et al., 2010). This was based on a previous study presented. Arguably, the latter presented the first thorough overview for supplier assessment criteria. The author reported a list of 23 criteria in addition to its importance.

Sustainable supply chain management (SSCM) was released to the field of operations and supply chain management by consolidating sustainable goals growth and SCM (Nujoom et al., 2019 & Nujoom et al., 2018a). Since then, the niche of SSCM is gaining a growing attention (Maditati et al., 2018; Ghadimi et al., 2019; Nujoom et al., 2016; Nujoom et al., 2018b and Jakhar et al., 2018). SSCM can be presented as "*the integration of supply chain management activities through improved supply chain relationships to achieve a sustainable competitive advantage*" Handfield and Nichols (1999). Supplier development, with a focus on sustainable development goals, plays a significant role towards SSCM advantages (Mohammed, 2019). Sustainable development aims at considering economic and ecological improvement. Economic sustainability includes traditional criteria such as purchasing cost, delivery

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reliability and products quality. Ecological sustainability refers to organizations' commitment to governmental regulations such as environmental legislation-certificate, waste management and energy consumptions towards zero pollution. Realizing the importance of sourcing decisions, selecting the best economic and ecological suppliers is crucial to boost the enterprise's competitiveness (Sellitto et al., 2019; Lin et al., 2018; and Tseng et al., 2019).

Supply chain activities are subject to intrinsic risks due to unforeseen disruptions. The latter, in supply chain context, can be defined as "*unplanned events that may occur in the supply chain which might affect the normal or expected flow of materials and components*" (Svensson, 2001). For instance, Tohoku earthquake (struck the eastern coast of Japan in May 2011) has caused enormous disturbances in supply chains of companies such as Toyota and the sectors of auto cars and retailers in the UK (Mohammed et al., 2018 and Tabuchi, 2011). This was due to the disruptions in supply happened to a number of suppliers due to power cut that followed that disaster. Toyota production for instance, has experienced a reduction over the following six months due to shortages of around 400 parts. Similarly, hurricane Sandy that caused by climate change, led to an enormous interruption in the US business (Burnson, 2012). Therefore, consideration of resiliency in supply chain risk management has revealed a growing interest in the last two decades. This argument was also supported in the literature (Bottani et al., 2019; Pettit et al., 2019; Sá et al., 2019; and Adobor and McMullen, 2018). Christopher and Peck, 2004 argued that resilient supply chain is achieved via its ability to return to its normal, or even better, state after a disruption. Similarly, Pendall et al. (2010) defined supply chain resilience as supply chain's capacity to work after disorder. Govindan et al. (2015) argued that supply chain resilience may not reveal to the cheapest attainment, however, it leads to a capable supply chain that could continue against the industry's uncertain environment. The latter are intended to be suppliers, customers and internal processes (Purvis et al., 2016). This research focuses on building resilient supply chain via suppliers considering the importance of sourcing is supply chain competitiveness.

Supply chain resiliency and sustainability is one of the significant interfaces seeking new development and improvement in supply chain management in a wider angle and a cross-niche perspective (Linton et al., 2007; and Fahimnia and Jabbarzadeh, 2016). Particularly, sustainable supply chains are probably prone to more expected or unexpected changes compared to traditional supply chains due to elements such as prompt fluctuations of consumers' behaviour or guidance of non-organizational firms (Hall, 2000). Further intersections between sustainability and resiliency in the context of supply chain are discussed in Section 2.1.

Despite the need for the simultaneous consideration of resiliency and environmental sustainability aspects in supply chain management, the literature lacks behind the consideration of the two aspects in purchasing context. Where the vast majority of current literature handle supplier selection problem considering green and resilience aspects, separately. In other words, there is a gap in managing supply chains, in particular supplier selection process, encountering green development and resilience enforcement. Hence, there is a call for an approach that helps managers to 'go green' without lacking supply chain resiliency.

This research bridges this gap in holistically addressing the supplier selection problem from resiliency and greenness perspectives. The aim of this research has threefold: (1) discuss and analyse the need and complementarities for or between resiliency and greenness in supply chain context; (2) recognize the criteria of resiliency (a new framework for resilient supplier was identified in considering criteria of development, agility, robustness, sensing and flexibility (DARSF) and green supplier assessment into a unified framework; (3) propose a quantitative approach to quantify the relative importance of resilience and green criteria via Decision Making Trial and Evaluation Laboratory (DEMATEL) and suppliers' performance via VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR). Furthermore, the work presents a real-world impact by experiencing the developed gresilient approach on a real case study aims to advance its supply chain resilience.

This article continues as follows: in Section 2, a thorough review on green, resilient and gresilient supplier selection was conducted; in Section 3, the proposed gresilient supplier selection approach is discussed; in Section 4, application and evaluation for the proposed approach was implemented; and in Section 5, conclusions are discussed.

2. Literature review

2.1. Need for gresilient suppliers

Green SCM has raised as a new model for organizations to satisfy its competitiveness and performance with respect to the new regulations and public awareness towards environmental sustainability (Islam et al., 2018). Wan et al. (2017) and Sarkar and Mohapatra, 2006 argued that the main green development goals is attaining a sustainable business and efficient environmentalism.

Supply chain resilience has been broadly discussed in previous research considering tactical, strategic, and operative aspects due to several business disruptions as a result of unexpected events (e.g., floods, tsunamis, and strikes). However, supply chain resiliency is not merely for improving risk management, but also seeking further development in SCM (Linton et al., 2007; Ivanov, 2017). Green supply chain management has been identified as one the intersection along with resilience in supply chains (Ivanov, 2017; Fahimnia et al., 2014; Chan et al., 2017; and Ramezankhani et al., 2018). As a matter of fact, green supply chain management is bounded by numerous inevitable disruption events that raises the need for a resilient supply chain suitability that can afford this dynamism. This is supported by Ivanov (2017), as argued that supply chain resilience and robust re-structure of supply chains prior to disruptions considering sustainability responsibilities are among main issues. Similarly, Giannakis and Papadopoulos (2016) emphasised the vital role of supply chain risk management in SSCM. Another intersection between resilience and sustainability is lied in the aim of sustainability in reduction of safety inventory and limit sourcing to sustainable suppliers only (Ahi and Searcy, 2015). This presents a kind of contradictory with the concept of resiliency that aims to improve supply chain robustness in having safety stock and multiple flexible suppliers.

Robust supply chain management is heavily counted on the supplier selection performance (Mohammed et al., 2017a,b). In this sense, an organization's performance and competitiveness development is dependant mainly on supplier selection decision, and thus positively impacts the company's sustainability state (Rodríguez et al., 2016). Where organizations broadly integrate sustainability elements into their supply chain management activities with an intensive focus on supplier selection decisions (Chai and Ngai, 2020; and Guarnieri and Trojan, 2019). To highlight these facts, the development of sustainable and resilient supply chains can be improved via the modelling and development of decision support systems from sustainability and resiliency perspectives (Giannakis and Papadopoulos, 2016; Brandenburg and Rebs, 2015; and Ivanov, 2017).

Notwithstanding, the vital correlation between sustainability and resilience in SCM, literature seeks the consolidating 'recipes' of these two aspects is still at an infant state (Mohammed et al., 2018; Ivanov, 2017; Fahimnia et al., 2014; and Mari et al., 2014). Brandenburg and Rebs (2015) presented a review study on SSCM reviewing 185 articles over the last 20 years in quantitative models. The need for exploring sustainability and resilience in supply chains using quantitative approaches has highlighted as future avenues. Simchi-Levi et al. (2015) created a risk management index towards a sustainable supply chain from customer satisfaction perspective. Ivanov et al., 2016 aimed at addressing the sustainable supply chain problem in terms of waste management. The author also proposed a model towards a resilient supply chain network. Fahimnia and Jabbarzadeh (2016) and Mari et al. (2014) presented a study to investigate the effects of green supply chain to its resiliency. Their research identified the possibility towards "*resiliently sustainable supply chain*". Ivanov (2017) analysed the intersections between sustainability and resiliency in SCM aiming to build a resilient SC along with uncertainty reduction and sustainability improvement.

2.2. Measuring supplier resiliency

Due to globalization, supply chains are becoming more vulnerable to unexpected disruptions. Therefore, resilient supply chain is currently merging an increasing challenge to decision makers in industry. Nevertheless, little attention is given to this area of knowledge (Hosseini et al., 2019; Parkouhi et al., 2019; and Kamalahmadi and Mellat-Parast, 2016). Ribeiro and Barbosa-Povoa (2017) presented a study to review research studies conducted to improve supply chain resiliency, as well as, its definitions. The authors concluded that very scarce quantitative research was performed to improve supply chain resilience. Also, the study identified the selection of supplier as a key-factor in attaining a resilient SC. This was also supported by Kuo and Lin (2011); Mohammed et al. (2019). Therefore, supplier selection considering resilience aspect is recently being increasingly emphasized.

For instance, a recent study by Parkouhi et al. (2019) proposed a DEMATEL-based approach to segment suppliers according to their resilience performance. Hosseini et al. (2019) extended the resilience supplier selection process in including the order allocation problem considering resiliency among alternatives. Parkouhi and Ghadikolaei (2017) considered flexibility, joint growth, supply constraints and buyer-supplier relationship as resiliency criteria to assess supplier performance. Rao et al. (2017) developed a supply chain risk management-multi-attribute auction- based approach to evaluate suppliers for divisible goods. Rajesh and Ravi (2015) identified four groups of attributes towards a resilient supplier selection approach. use Grey. Adtiya et al. (2014) proposed a decision-making approach to assess suppliers vis-à-vis resilience performance in terms of criteria such as flexibility, multiple sourcing, strategic stock, etc. With a focus on disruption risk, Sawik (2013) formulated a multiple objective optimization model that modelled a supplier selection problem for a supply chain.

Although several review studies have been conducted on supply chain resilience (Ho et al., 2015; Colicchia and Strozzi, 2012; Hosseini et al., 2019 and Parkouhi et al., 2019), it is obvious resilience criteria in supply chains are not unified. Teece (2007) argued that enterprise should have the capabilities of "*sensing opportunities, seizing them, and reconfiguring itself around them*". Ponomarov, 2009 argued that flexibility/redundancy, agility, complexity, visibility, structure and knowledge, reduction of uncertainty, reengineering collaboration, integration, operational capabilities and transparency are the main resilience pillars. While, Carvalho et al. (2012) limited these criteria to flexibility and redundancy. Sawik (2013) discussed that risk-averse, risk-neutral and mean-risk are enablers of disruptions. Flexibility of supplier performance was also identified as a mean towards less effective disruption impact (Kamalahmadi and Mellat-Parast, 2016). Purvis et al. (2016) presented a new framework for SC resilience so-called RALF (robustness, agility, leanness and flexibility). However, the criterion of leanness may not be applicable to all sectors in industries. In this work, a novel framework for resilient supplier was drawn out in considering criteria of development, agility, robustness, sensing and flexibility (DARSF). Table 1 presents definition to these criteria. The criterion of development (D) was also considered, realizing the significant importance to the organization to learn from the experienced disruption and accordingly develop its capabilities.

2.3. Measuring supplier greenness

In the last two decades, environmentalism is challenging organization to not merely adapt internal environmental (green) improvement, but also broaden it to a comprehensive green supply chain management. Particularly, nowadays as never before, there is a vast growing attention and awareness regarding climate changes and 'go green' concepts (World Development Report, 2015; Fang and Zhang, 2018). In the decade, several research studies have been accomplished aimed at improving green SCM (Rajeev et al., 2019; and Hu et al., 2019). In this sense, green supplier selection was one of the main investigated streams considering the significant importance of suppliers in improving supply chain performance (Sellitto et al., 2019; and Lin et al., 2018). These studies were normally to provide the purchasing team with a guidance regarding the green criteria in assessing suppliers. Similar to resilience criteria, there is no specific green criteria in supply chain context either by governmental regulations or environmental organizations. Igarashi et al. (2013) performed a review research for 60 research papers on green supplier selection between 1991 and 2011.

For instance, Zhu et al. (2010) presented a performance–based analytic approach in ranking suppliers vis-à-vis green aspect. Fu et al. (2012) applied MCDM in evaluating the green performance of supplier in the telecommunication sector. Wang and Chan (2013) developed a fuzzy Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS)-based method towards an enhanced green organizational performance. Mohammed et al. (2018a) developed a hybrid integrated methodology to evaluate green performance in a two-tier supplier in a food industry. Considering the three dimensions of sustainable development, Songa et al. (2017) presented an approach for selecting suppliers via DEMATEL. Banaeian et al. (2018) incorporated environmental criteria into the traditional supplier selection decision using fuzzy MCDM methods.

2.4. Supplier assessment

The evaluation and selection of suppliers represents a vital process in SCM, and it consists of a number of stages (Van Weele, 2010), as shown in Fig. 1. The purchasing team, department or section is normally responsible for this activity in industry. The team may include junior buyers, buyers, senior buyers and a purchasing manager or a supply chain manager. The team normally start in identifying (1) the need for suppliers for particular items; and (2) the assessment criteria for supplier performance. This is followed by a call for tender from the identified suppliers. Then, the purchasing team evaluate supplier performance either based on history or intuition based on submitted tenders. This stage normally includes a supplier visit and meeting(s) with potential qualified suppliers to supply related items. However, the selected supplier is typically still subject to a regular evaluation. Over the last two decades, there is a growing complexity regarding supplier assessment/selection due to the consideration of several quantitative and qualitative factors, in addition to traditional factors (e.g., price and quality). Particularly, supplier assessment/selection is a crucial key-factor in improving organizational competitiveness and future development (Tseng et al., 2019; Ho et al., 2010; Mohammed et al., 2018a). Realizing the multiple factors in assessing and selecting suppliers, MCDM algorithms are needed.

2.5. Approaches for supplier selection

So far, load of mathematical methods has been created and proposed to assess and select suppliers, starting from mono objective to complex multiple objectives algorithms. A number of review studies were conducted to review supplier selection problem and adopted methods (Chai et al., 2013). Among the several proposed MCDM methods, approaches such as VIKOR and TOPSIS were highlighted among the most popular approaches (Opricovic and Tzeng, 2004; Gul

Table 1
Definitions of resilience criteria (DARSF).

Enabler	Definition
Development	Not only return to an original state upon a disruption but growing to an improved state. Also, it describes the possibility of an enterprise to learn and merge new approaches in response to risk events.
Agility	Assess supplier's capacity to react to potential changes of competitors in a rapid and well-oriented format, via the existence of a partner capable to cope with unanticipated demand.
Robustness	Assess supplier's capacity to withstand interruptions via the existence of stand by suppliers or having the capability to present new suppliers quickly.
Sensing	Detecting and evaluating opportunities of disruptions outside your enterprise. This would be achieved by sharing relevant information which would improve sensing of unexpected orders and fulling them.
Flexibility	Measure the ability to react smoothly to interruptions in the sourcing, along with control of costs and lead-times.

et al., 2016; Dukyil et al., 2017; Opricovic and Tzeng, 2004 and Chen and Wang, 2009a, b). Although TOPSIS recommends the best alternative that is closest to the ideal solution and furthest from the worst solution, it does not encounter the correspondence importance of these distances (Opricovic and Tzeng, 2004). Also, the association among criteria is not considered in TOPSIS. The latter may struggle in quantifying criteria along with a consistent evaluators' judgment, particularly with high number of criteria (Opricovic and Tzeng, 2004; and Mohammed et al., 2019b). On the other hand, VIKOR can present a trade-off to reflect the preferences of most evaluators. Also, it presents information on individual regret and maximum group utility referring to the most insufficient enabler or criterion. It works on assessing and selecting from a group of alternatives. The later helps in obtaining a trade-off for decision making problems considering contradicting criteria and enablers (Liou and Chuang, 2010a; b). Therefore, VIKOR has been widely employed in MCDM problems (Sahu et al., 2016; Wang et al., 2009; Shemshadi et al., 2011; Chang, 2014; Liu et al., 2014; Sanayei et al., 2010; Vahdani et al., 2013).

The DEMATEL algorithm was also identified as a popular algorithm in solving decision-making problems (Si et al., 2018). It is developed for solving complex MCDM problems as it can verifies interdependence between parameters and reflects interrelationships among variables as causes and effects. Hsu et al. (2013) presented a DEMATEL-based approach for a green supplier selection decision. A similar study, in DEMATEL context, was presented by Büyüközkan and Çifçi (2012). Naser et al. (2010) used DEMATEL to perform an environmental analysis. Ru-Jen (2011) performed an evaluation of supply chain management considering greenness aspect by using DEMATEL. Fu et al. (2012) applied DEMATEL for evaluating the green performance of supplier in the telecommunication sector. For further details on advantages of the VIKOR and DEMATEL methods, we refer readers to the recent review studies conducted by Gul et al. (2016) and Si et al. (2018), respectively.

3. Gresilient supplier selection: Research methodology

The development of green supply chains is a trend world-wide aspect of the 21 st century responding to the increasing environmental responsibilities that concerned public in recent years. Because of the vulnerability of supply chain risks towards disruptions, a growing attention is giving to improve supply chain resiliency. Realizing these perspectives and the aforementioned intersections (see section 2.1) between resilience and environmental sustainability, there is a need to start considering them simultaneously towards the achievement of gresilient development goals.

In this work, a laboratory instrumentation Original Equipment Manufacturer (OEM) was studied. The company aims to improve its purchasing strategy in improving supplier assessment approach considering resiliency in order to react for unexpected events. Besides, environmental sustainability development was recommended to the company to improve its competitiveness. Therefore, this research aims at identifying a gresilient supplier selection approach to support the purchasing department decision. Based on literature and discussion with the purchasing manager, the gresilience criteria were identified into three dimensions as presented in Fig. 2.

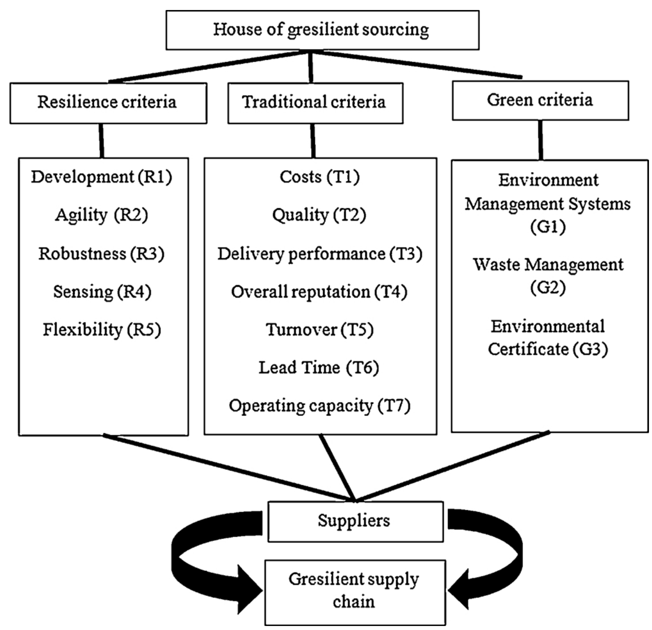

Fig. 2. House of gresilience criteria.

After identifying gresilience criteria, the DEMATEL algorithm was used to determine the relative importance of criteria based on opinions from the purchasing team. Then, the gresilience performance of suppliers was assessed by using the VIKOR algorithm. Next, the overall performance of suppliers was revealed and insights for the gresilience state, in terms of suppliers, were discussed. Following this performance assessment, three actions will be suggested: (1) in case of an acceptable gresilience performance revealed, no action is required; (2) in case of weak gresilience performance revealed, the purchasing team needs to work with current suppliers to improve their gresilience capabilities; and (3) in case of very weak gresilience performance revealed, the purchasing team needs to seek new suppliers to switch from those very weak suppliers, in particular for critical items.

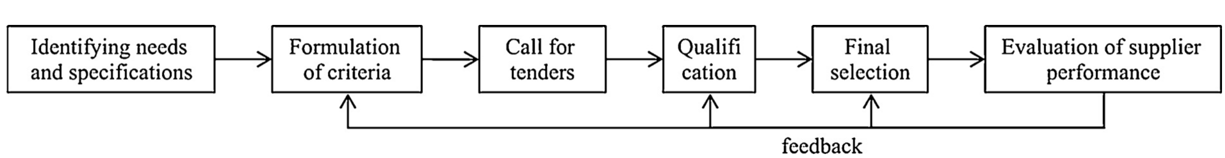

Fig. 1. Stages of supplier selection process (Van Weele, 2010).

3.1. DEMATEL: Quantifying gresilience criteria

United States Bastille laboratory proposed Decision Making Trial and Evaluation Laboratory (DEMATEL), in 1971. Unlike the traditional Analytic Hierarchy Process (AHP) method proposed by Saaty (1977), this approach considers the independencies among dimensions and enablers using DEMATEL in addition to obtaining the importance degree of the dimensions and enablers. This way appears to be more comprehensive and reasonable because cause enablers truly have strongly impact on effect enablers and this interrelationship should be taken into account. Thus, it makes it more straightforward to guide the managers to identify the most conclusive determinants. Furthermore, DEMATEL uses the advantage of making improved decisions in various environments (Si et al., 2018). Hence, it is widely used to reveal the influence level among criteria due to of its powerful. The application of DEMATEL method is presented in Appendix A.

3.2. VIKOR: Assessing suppliers

Serafim Opricovic was first who presented the compromise ranking method so-called VIKOR as a MCDM algorithm (Opricovic, 1998). It aims to assess and rank alternatives according to their distances from the positive and negative ideal solution (Opricovic and Tzeng, 2004). It can present a trade-off to reflect the preferences of most evaluators. Also, it presents information on individual regret and maximum group utility referring to the most insufficient enabler or criterion. It works on assessing and selecting from a group of alternatives. The later helps in obtaining a trade-off for decision making problem considering contradicting criteria and enablers (Chen and Wang, 2009a; b and Opricovic and Tzeng, 2007a; b). In this research, VIKOR was used to assess and rank suppliers vis-à-vis gresilience performance. In this work, the VIKOR algorithm was applied as illustrated in Appendix A.

4. Application and results

In this section, the applicability and practicality of the presented gresilience supplier selection approach on a real application is explored. The case under study is a chemical manufacturing company ((Company A, henceforth) that assembles chemistry measurement equipment in the UK. Company A is a leading company and factory of scientific instruments for thermal desorption and time-of-flight mass spectrometry. Products designed and manufactured by Company A are applied in various application areas e.g. quality control & safety of food products and environmental monitoring. Company A aims to improve its purchasing sourcing towards an ultimate goal of improving its SC resilience. The latter is part of a plan to meeting the company expansion goal by 2020. This research aimed at supporting the purchasing team in improving their purchasing strategy in terms of assessing suppliers. In its current state, the latter is solely based on traditional criteria with a potential to include resilience criteria. Realizing the growing regulations about environmentalism, it was recommended to the purchasing manager to include green criteria. However, the purchasing team had no idea about the main resilience, in addition to green, criteria that should be considered into the evaluation process. Therefore, traditional, green and resilience criteria (gresilience) (see Fig. 2) were first identified and discussed with the purchasing manager (PM) over two 2 h (around) meetings. It is worthy to mention that this helped in educating the purchasing team towards the importance and criteria of resiliency and greenness. Second, a DEMATEL-VIKOR decision making approach was developed based on these criteria to assess and choose suppliers vis-a-vis their gresilience performance. The PM nominated (1) five suppliers of metal-sheet to validate the proposed approach; and (2) two buyers to perform the evaluation process.

4.1. Quantifying gresilience criteria weight: DEMATEL

In this sub-section, the relative importance of gresilience criteria (traditional business, green and resilience) were measured via the DEMATEL algorithm. The latter was applied as follows:

In stage 1: an individual interview with the three decision makers (D1, D2 and D3) from the purchasing team were held to generate the linguistic (based on Table A1 in Appendix A) comparison matrix regarding the gresilience criteria.

In stage 2: the linguistic comparison matrix was transformed to the correspondence numerical matrix as shown Table B1 in Appendix B. The numerical pairwise comparison was generated based on a 0–4 scale (see Table B1 in Appendix B).

In stage 3: Eq.1 was applied to generate the aggregated normalized decision matrix (see Table B2 in Appendix B).

In stage 4: Eq. 3 was applied to generate the total-influence matrix (T) as shown in Table B3 in Appendix B.

In stage 5: Eqs. 5 and 6 were applied to determine values of vectors D and R respectively (see Table B4 in Appendix B). In stage 6: The summation and subtraction of D and R (D + R) and (D–R). Resilience criteria turned out the highest net influence level tailed by the traditional criteria and green criteria, respectively.

In stage 7: Eq. 7 was used to reveal weight of gresilience criteria as shown in Table 2. This was measured by normalizing the total influence vector (D + R) obtained from stage 6. As shown in Table 2, resilience criteria attained the highest importance weight (0.386) tailed by traditional criteria (0.333) and then green criteria (0.281), respectively.

4.2. Assessing and ranking suppliers: VIKOR

In this sub-section, the gresilience performance of the five suppliers was assessed via the VIKOR algorithm. The latter was applied as follows:

In stage 1: The three decision makers (D1, D2 and D3) from the purchasing team were invited to linguistically evaluate suppliers' gresilience performance. The linguistic evaluation was performed based on the scale shown in Table A2 in Appendix A.

In stage 2: The linguistic evaluation from stage 1 was transformed to the correspondence numerical evaluation as shown in Table C1 in Appendix C.

In stage 3: Eqs. 8 and 9 were applied to attain normalized and weighted normalized values (see Table C2 in Appendix C).

In stage 4: Elements $((f^{+})\text{-}f_{jn}$ and $w_i{*}(((f^{+})\text{-}f_{jn})/(f^{+})\text{-}(f^{-})))$ of Eqs. 12 and 13 were determined as shown in Table C2 in Appendix C.

In stage 5: Eqs. 12–14 were applied to determine the distance of the

Table 2
Relative importance related to gresilience criteria.

Criteria	Importance weight
T	0.333
G	0.281
R	0.386
T1	0.390
T2	0.387
T3	0.223
T4	0.337
T5	0.348
T6	0.379
T7	0.346
G1	0.368
G2	0.342
G3	0.289
R1	0.227
R2	0.378
R3	0.394
R4	0.196
R5	0.355

Table 3
S_j, R_j and Q_j values related to VIKOR.

	Sj	Rj	Qj
S1	0.209	0.111	1.000
S2	0.988	0.394	0.702
S3	1.880	0.394	0.720
S4	0.577	0.025	1.210
S5	1.355	0.394	0.861

supplier's performance to the positive ideal solution (S_j), the maximal regret of each suppliers (R_j) and measuring index (Qi), respectively. The results are reported in Table 3.

In stage 6: The gresilience (GR) value for the five suppliers was determined by summing the three measures (S_j, R_j and Q_j). Based on VIKOR, the lowest GR value reflects the highest performance of a supplier. Fig. 3 shows a graphical illustration regarding the obtained GR values.

In stage 7: The previous stages were applied considering traditional, green and resilience criteria individually as shown in Fig. 4 and Table 4.

As shown in Fig. 3, arguably, the five suppliers revealed low gresilience performance that is far from the ideal performance value (0). Supplier 1 turned out to be the best supplier with the lowest GR value of 1.321 compared to supplier 3 that revealed the worst gresilience performance with the highest GR value of 2.994.

4.3. Discussions and implications

Over the last two decades, the pursuit of green SCM has attained an extensive consideration by practitioners and researchers. On the other side, supply chain resilience is becoming a growing concern for decision makers in industry due to their awareness of risks of business disruptions. Despite the numerous intersections and relationships between resiliency and greenness in supply chain, literature on resilient and green SCM, in particular purchasing, is still scarce. Correspondingly, the individual evaluation of greenness or resiliency of suppliers has been thoroughly studied. This research puts forward an early attempt in supplier selection decision towards gresilient supply chain management.

Generally speaking, resilience criteria released the highest relative importance tailed by the traditional criteria leaving the green pillars as the least importance. The traditional business criteria normally attain the highest weight. Thus, it is expected that the traditional business criteria would achieve the highest importance once the company resilience is assured. This was also evident by the PM who clarified this due to current company trend to improve its resiliency.

Based on the three actions to be considered based on supplier's performance (acceptable gresilience performance → no action; weak gresilience performance → work with current suppliers to improve their gresilience capabilities; very weak gresilience performance → seek new suppliers to switch from very weak suppliers):

1 None of the five suppliers revealed acceptable gresilience performance (GR value < 1). Therefore, the purchasing manager was heavily encouraged to discuss this issue with the purchasing team putting a strategic plan towards gresilient sourcing. It is noteworthy, regardless resilience criteria, supplier 1 has revealed acceptable traditional and green performance. In other words, supplier 1 needs to improve its resilience performance to attain an overall acceptable gresilience performance. Thus, this study may help supplier 1 to identify the main resilience criteria that need to be adapted into its development plan to sustain its competitiveness.
2 Suppliers 1 and 4 revealed weak gresilience performance (1 ≤ GR value < 2). Therefore, the purchasing manager needs to discuss the possibility of gresilience performance with suppliers 1 and 4.
3 Suppliers 2, 3 and 5 revealed very week gresilience performance (GR value ≥ 2). Therefore, the purchasing manager needs to inform suppliers 2, 3 and 5 to either agree on improving their gresilience performance within 6 months scheduled plan or lose the collaboration with the company.

Thus, this research educated the purchasing team towards the paramount need for considering green and resilience criteria rather traditional supplier evaluation vis-à-vis traditional criteria. It also helped the purchasing team how to support the ultimate goal of the company towards a resilient business. This includes the identification of resilience criteria that should be considered into the supplier evaluation process. Arguably, this research re-shaped the current traditional purchasing strategy to a gresilient purchasing strategy. Therefore, this research can be successfully employed as aid tool by managers that aim to improve their business "gresiliency". It provides them with a holistic insight towards gresilient advantages in today' highly competitive business. Similarly, it may help suppliers, such as supplier 1 in this work, diagnose and improve their work towards the identified criteria.

4.4. Sensitivity analysis

In this section, sensitivity analysis was accomplished on the derived, via VIKOR, results of suppliers' ranking order based on their gresilience performance. This process was conducted to explore the stability of the proposed approach by varying criteria' relative importance. To this end, 4 different combinations (C1–C4) of gresilience criteria (see Fig. 2)

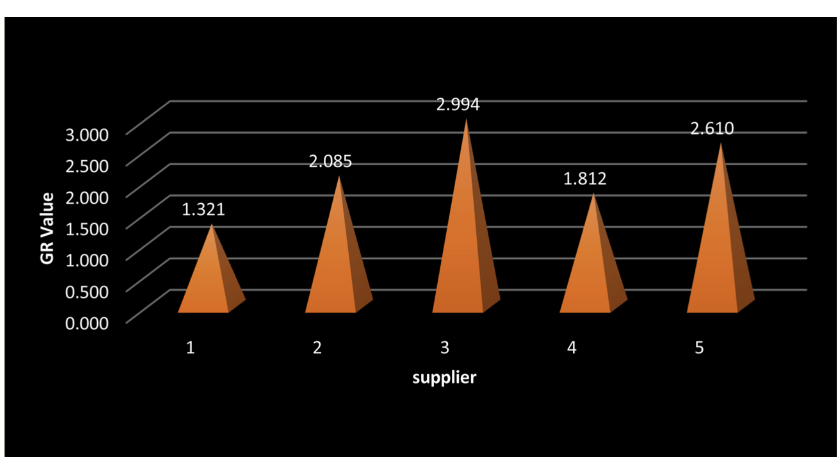

Fig. 3. Gresilience performance (GR) of suppliers via VIKOR.

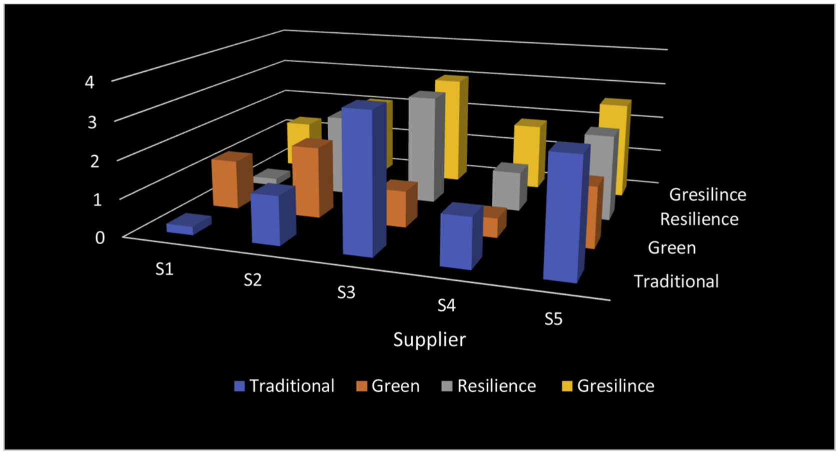

Fig. 4. Traditional, green, resilience and gresilience performance of suppliers via VIKOR (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Table 4
Individual gresilience performance related to VIKOR.

Supplier	Traditional	Rank	Green	Rank	Resilience	Rank	Gresilience	Rank
S1	0.223	1	0.223	1	1.196	1	1.321	1
S2	1.285	2	1.285	2	2.189	3	2.085	3
S3	2.908	5	2.984	4	2.944	5	2.994	5
S4	1.290	3	1.290	3	1.060	2	1.812	2
S5	2.984	4	2.918	5	2.277	4	2.610	4

Table 5
Suppliers rank' sensitivity analysis by varying criteria weights.

OW	OR	C1	R1	C2	R2	C3	R3	C4	R4
0.390	1	0.351	1	0.298	1	0.328	2	0.358	1
0.387	3	0.348	3	0.296	3	0.326	3	0.355	3
0.223	5	0.201	5	0.171	4	0.188	5	0.205	4
0.338	2	0.304	2	0.259	2	0.284	1	0.310	2
0.348	4	0.313	4	0.266	5	0.293	4	0.319	5
0.380		0.342		0.291		0.320		0.349	
0.346		0.311		0.265		0.291		0.318	
0.368		0.331		0.282		0.310		0.338	
0.342		0.308		0.262		0.288		0.314	
0.289		0.260		0.221		0.243		0.265	
0.227		0.272		0.354		0.283		0.212	
0.378		0.454		0.590		0.472		0.354	
0.394		0.473		0.615		0.492		0.369	
0.196		0.235		0.306		0.245		0.183	
0.355		0.426		0.554		0.443		0.332	

OW: original weight; OR: original rank; R: Rank; C: weight combination.

weights were applied in Eq. 8, individually. These weights were increased/decreased by 10% and 20% compared to the obtained weights. Table 5 list the new corresponding 4 ranking orders out of this process. For instance, the first column (C1) shows the original weights wherein column C2 shows an increase in both traditional and resilience weights by 10% with a decrease in resilience weight by 20%. As shown in Table 5, the results revealed almost same ranking orders along the five iterations of VIKOR application which proved the robustness of the proposed assessment approach.

5. Conclusions: Towards gresilient sourcing

Supplier assessment/selection is one of the crucial organizational decision that should be cautiously taken since an unsuitable sourcing may economically threat the position of organization and result in a deterioration of service level. The 'go green' concept has raised as a growing organizational need towards achieving the environmental sustainability goals. Resilience concept in supply chains is a crucial aspect that should merged into the environmental sustainability development plan due several intersections in between (Linton et al., 2007; Ivanov, 2017). Notwithstanding, the integration of resilience and green aspects into SCM, in particular in purchasing, has been rarely presented in the literature.

This work proposes a conceptual traditional business, green and resilient (gresilient) supplier assessment/selection approach. This includes (1) a thorough analysis of the literature to highlight the need for greenness and resiliency in supply chain management; (2) development of a new framework for supplier resiliency (DARSF); (3) presenting gresilience criteria into a holistic conceptual framework; (4) measure the relative importance of gresilience criteria via DEMATEL; and (5) quantify the gresilience performance of suppliers vis-à-vis identified criteria via VIKOR. The research outcome demonstrates the superiority of resilience criteria over traditional and green criteria. This is out of normal traditional expectations in industry where decision makers give the highest attention to traditional criteria such as quality and cost. This outcome could be biased by the current trend of high-level managers at the company towards a resilient business. Also, it was noticed generally that current suppliers have weak gresilience performance. Furthermore, the purchasing team needs to either encourage three suppliers to improve their performance or switch to new suppliers within a 6 months plan.

In this research, green and resilience aspects was experienced on a strategic level of supplier selection. Thus, it would be useful to explore the impact of gresilience consideration into tactical level in terms of allocating the optimal order of products to be ordered from each supplier based on their gresilience performance. This requires a multi-objective optimization model integrating the suppliers' gresilience performance revealed via VIKOR. Also, in this research, social sustainability criteria were not measured upon the need of current study. Further research can include the three dimensions (i.e., economic, environmental and social) of sustainability along with resiliency. Considering the impacts of uncertainty in decision makers 'opinions, it would be recommended to adapt fuzzy set theory into the evaluation process. This will also boost the industrial applicability of the presented gresilient approach. Furthermore, comparison of the DEMATEL-VIKOR approach with other MCDM algorithms are also recommended to investigate its robustness and superiority in selecting gresilient suppliers. Finally, the gresilience approach was applied on a chemical manufacturing industry, and it would recommend applying on other sectors such as food and conduction industry. This will probably re-shape the gresilience criteria such as consideration of food quality, monitoring of food during transportation, etc.

Declaration of Competing Interest

We confirm that there is no conflict of interest with the editorial board and the anonymous reviewers.

Appendix A

DEMATEL

The application of DEMATEL method is as follows (Tzeng et al., 2007; and Mohammed et al., 2019a; b):

Step 1: Generate the direct-relation matrix C (Eq.1) via a pairwise comparison between criteria using the influence scale presented in Table A1.

$$C = \frac{C_1 + C_2 + \ldots + C_m}{m} = \begin{bmatrix} 0 & c_{12} & \ldots & c_{1i} & \ldots & c_{1n} \\ c_{21} & 0 & \ldots & c_{2i} & \ldots & c_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ c_{i1} & \ldots & \ldots & \ldots & \ldots & c_{in} \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ c_{n1} & c_{n2} & \ldots & c_{ni} & \ldots & 0 \end{bmatrix} \tag{1}$$

where m and n denote the number of participants and the number of criteria, respectively, and $C_1, \ldots, C_m$ refer to the direct-relation matrices for m participants.

Step 2: Compute the normalised direct-relation matrix N by using Eqs. 2 and 3.

$$N = x \cdot C\# \tag{2}$$

where

$$x = min\left[\frac{1}{max_{j=1,\ldots,n}\sum_{i=1}^{n} c_{ij}}, \frac{1}{max_{i=1,\ldots,n}\sum_{j=1}^{n} c_{ij}}\right] \tag{3}$$

Step 3: Generate the total-relation matrix T via Eq. 4. This matrix depicts the total relationship including direct influence and indirect influence between each pair of criteria.

$$T = N\,(\mathrm{I} - \mathrm{N})^{-1} \tag{4}$$

where I denotes the identity matrix.

Step 4: Divide the criteria into causes and effects group by computing the $D_k + R_k$ value called "prominence" and $D_k - R_k$ value called "relation" for each criterion. The D_k and R_k are the rows sum and columns sums of matrix (T) respectively, as presented in Eqs. 5 and 6 respectively.

Table A1
Influence scale related to DEMATEL.

Linguistic Variable	Scale
No influence (NI)	0
Low influence (LI)	1
Medium influence (MI)	2
High influence (HI)	3
Very high influence (VHI)	4

Table A2
Equivalent scale used for evaluating suppliers 'gresilience performance.

Linguistic assessment scale	Numerical scale
Very low (VL)	1
Low (L)	3
Medium (M)	5
High (H)	7
Very high (VH)	9

$$D_k = \sum_{j=1}^{n} t_{kj},\ for\ \ k = 1, \ldots, n, \tag{5}$$

$$R_k = \sum_{i=1}^{n} t_{ik},\ for\ \ k = 1, \ldots, n, \tag{6}$$

Any criterion would be categorized as (i) a cause when its "relation" value (i.e. $D_k - R_k$) is positive; and (ii) an effect when its "relation" value is negative.

Step 5: Measure criteria weight w_n as follows:

$$w_n = \frac{D_k + R_k}{(\sum_{k=1}^{n} (D_k + R_k))} \tag{7}$$

VIKOR

The VIKOR was applied as follows (Opricovic, 1998; Wang et al., 2019; and Rani et al., 2019):

1. Build the decision matrix A_{jn} as the number of matrix rows (j) and matrix columns (n) refer to the alternatives and the criteria respectively. This matrix is built according to the decision makers 'experts based on the assessing scale shown in Table A2.

$$A_{jn} = \begin{bmatrix} r_{11} r_{12} r_{1n} \\ r_{21} r_{22} r_{2n} \\ \ldots \\ \ldots \\ r_{j1} r_{j2} r_{jn} \end{bmatrix}$$

2. Calculate the normalized values N_{ij}, where r_{jn} is the main value, as follows

$$N_{jn} = \frac{r_{jn}}{\left(\sqrt{\sum_{j=1}^{x} r_{jn}^2}\right)},\ j = 1,\ \ldots,x;\ \ n\ =\ 1,\ \ldots,y \tag{8}$$

where r_{jn} refers to the performance of alternative j vis-à-vis criterion n; and, x and y refer to the alternatives and the criteria respectively.

3. Generate the weighted normalized values as follows

$$f_{jn} = N_{jn}.\ w_n \tag{9}$$

Where w_n is the weight of gresilience criteria derived from the DEMATEL algorithm (see Eq. 7).

4. Determine the positive ideal solution (f_j^*) and the negative ideal solution (f_j^-) using Eqs. 10 and 11, respectively. f_n^* and f_n^- refer to the best and worst in each criterion, respectively.

$$f_n^* = \max f_{jn} \tag{10}$$

$$f_n^- = \min f_{jn} \tag{11}$$

5. Compute the values Si and Ri as follows

$$S_j = \sum_{n=1}^{x} w_n (f_n^* - f_{jn})/(f_n^* - f_n^-) \tag{12}$$

where x refers to the criteria.

$$R_j = \max_n [w_n (f_n^* - f_{jn})/(f_n^* - f_n^-)] \tag{13}$$

where w_n is the criteria weight derived from DEMATEL. f_{jn} denotes alternative j' s weighted normalized value with respect to criterion n (see Eq. 9). S_j is the distance of the supplier performance to the positive ideal solution; and R_j is the maximal regret of each supplier. Sj and Rj are in the [0,1] in which 0 and 1 are best and worst conditions, respectively.

6. Determine the measuring index Q_j as follows:

$$Q_j = v(\frac{S_j - S^-}{S^* - S^-}) + (1 - v)(\frac{R_j - R^-}{R^* - R^-}) \tag{14}$$

Where $S^* = \max_j S_j$ for suppliers assessment and $S* = 1$ for dynamic capability assessment; $S^- = \min_j S_j$ for suppliers assessment and $S^- = 0$ for dynamic capability assessment; $R^* = \max_j R_j$ for suppliers assessment and $R* = 1$ for dynamic capability assessment; $R^- = \min_j R_j$ for suppliers assessment and $R^- = 0$ for dynamic capability assessment; and v and $1\text{-}v$ are weights for the strategy of maximum group utility and the individual regret, respectively. v value ranges from 0 to 1. Generally, $v = 0.5$ is assigned when the decision process involves both maximum group utility and individual regret (Opricovic, 1998; Wang et al., 2019 and Rani et al., 2019). It should be noted that the computation of S_j, R_j and Q_j need to be conducted for each alternative with respect to all criteria.

Appendix B

Table B1
Aggregated decision matrix among gresilience criteria.

Criteria	T		G			R	
T	0		3			2	
G	0		0			1	
R	4		3			0	
Traditional	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
T1	0	4	2	0	2	3	3
T2	4	0	0	4	3	1	3
T3	2	0	0	3	1	0	0
T4	1	3	1	0	0	0	0
T5	2	0	3	4	0	1	4
T6	2	2	4	4	2	3	0
T7	1	2	0	4	4	3	0
Green	**G1**		**G2**			**G3**	
G1	0		4			4	
G2	2		0			4	
G3	0		0			0	
Resilience	**R1**		**R2**	**R3**	**R4**	**R5**	
R1	0		3	3	2	1	
R2	1		0	4	0	4	
R3	0		4	0	0	4	
R4	1		0	4	0	4	
R5	0		2	2	0	0	

Table B2
Normalized aggregated decision values among gresilience criteria.

Criteria	T			G		R	
T	0			0.4286		0.2857	
G	0.0000			0		0.1429	
R	0.5714			0.4286		0	
Traditional	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
T1	0	0.2105	0.1053	0.0000	0.1053	0.1579	0.1579
T2	0.2105	0	0.0000	0.2105	0.1579	0.0526	0.1579
T3	0.1053	0.0000	0	0.1579	0.0526	0.0000	0.0000
T4	0.0526	0.1579	0.0526	0	0.0000	0.0000	0.0000
T5	0.1053	0.0000	0.1579	0.2105	0	0.0526	0.2105
T6	0.1053	0.1053	0.2105	0.2105	0.1053	0	0.0000
T7	0.0526	0.1053	0.0000	0.2105	0.2105	0.1579	0
Green	**G1**			**G2**		**G3**	
G1	0			0.5000		0.5000	
G2	0.2500			0		0.5000	
G3	0.0000			0.0000		0	
Resilience	**R1**	**R2**		**R3**	**R4**	**R5**	
R1	0	0.2308		0.2308	0.1538	0.0769	
R2	0.0769	0		0.3077	0.0000	0.3077	
R3	0.0000	0.3077		0	0.0000	0.3077	
R4	0.0769	0.0000		0.3077	0	0.3077	
R5	0.0000	0.1538		0.1538	0.0000	0	

Table B3
The total-influence matrix (T) among gresilience criteria.

Gresilience	T			G		R	
T	0.2677			0.7441		0.4685	
G	0.1102			0.1299		0.1929	
R	0.7717			0.9094		0.3504	
Traditional	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
T1	0.2041	0.3705	0.2592	0.3160	0.2988	0.3260	0.3115
T2	0.3712	0.2087	0.1630	0.4641	0.3294	0.2255	0.3188
T3	0.1601	0.0819	0.0564	0.2296	0.1036	0.0529	0.0600
T4	0.1304	0.2147	0.0950	0.1020	0.0732	0.0555	0.0699
T5	0.2434	0.1702	0.2688	0.4245	0.1510	0.1859	0.3076
T6	0.3000	0.2928	0.3742	0.4835	0.2666	0.3068	0.1497
T7	0.2285	0.2740	0.1665	0.4632	0.3502	0.2981	0.1531
Green	**G1**			**G2**		**G3**	
G1	0.1429			0.5714		0.8571	
G2	0.2857			0.1429		0.7143	
G3	0.0000			0.0000		0.0000	
Resilience	**R1**	**R2**		**R3**	**R4**	**R5**	
R1	0.0478	0.4607		0.4986	0.1612	0.4254	
R2	0.0983	0.2622		0.5010	0.0151	0.5547	
R3	0.0366	0.4704		0.2364	0.0056	0.5297	
R4	0.0983	0.2622		0.5010	0.0151	0.5547	
R5	0.0207	0.2665		0.2673	0.0032	0.1668	

Table B4
Total influence and net influence levels related to gresilience criteria.

Objective	D	R	D + R	D-R
T	1.4803	1.1496	2.6299	0.3307
G	0.4331	1.7835	2.2165	−1.3504
R	2.0315	1.0118	3.0433	1.0197
T1	2.0861	1.6378	3.7239	0.4484
T2	2.0808	1.6128	3.6936	0.4680
T3	0.7445	1.3831	2.1276	−0.6386
T4	0.7407	2.4830	3.2237	−1.7423
T5	1.7514	1.5727	3.3241	0.1787
T6	2.1736	1.4507	3.6243	0.7229
T7	1.9335	1.3706	3.3042	0.5629
G1	1.5714	0.4286	2.0000	1.1429
G2	1.1429	0.7143	1.8571	0.4286
G3	0.0000	1.5714	1.5714	−1.5714
R1	1.5937	0.3017	1.8954	1.2919
R2	1.4313	1.7220	3.1533	−0.2906
R3	1.2788	2.0044	3.2831	−0.7256
R4	1.4313	0.2003	1.6316	1.2311
R5	0.7246	2.2314	2.9560	−1.5068

Appendix C

Table C1
Decision matrix related to VIKOR.

Supplier	T1	T2	T3	T4	T5	T6	T7	G1	G2	G3	R1	R2	R3	R4	R5
S1	9	7	5	7	7	7	7	5	5	5	5	5	5	5	7
S2	7	7	5	5	5	5	7	5	3	3	5	3	3	5	5
S3	5	5	3	3	1	3	3	1	1	1	3	3	3	3	1
S4	7	7	5	7	5	5	5	3	3	5	3	5	5	7	3
S5	5	3	7	5	3	5	3	3	1	1	3	5	3	3	3

Table C2
Output related to VIKOR.

Supplier	T1	T2	T3	T4	T5	T6	T7	G1	G2	G3	R1	R2	R3	R4	R5
S1	0.59	0.52	0.43	0.56	0.67	0.61	0.59	0.60	0.75	0.64	0.57	0.52	0.57	0.46	0.73
S2	0.46	0.52	0.43	0.40	0.48	0.43	0.59	0.60	0.45	0.38	0.57	0.31	0.34	0.46	0.52
S3	0.33	0.37	0.26	0.24	0.10	0.26	0.25	0.12	0.15	0.13	0.34	0.31	0.34	0.28	0.10
S4	0.46	0.52	0.43	0.56	0.48	0.43	0.42	0.36	0.45	0.64	0.34	0.52	0.57	0.65	0.31
S5	0.33	0.22	0.61	0.40	0.29	0.43	0.25	0.36	0.15	0.13	0.34	0.52	0.34	0.28	0.31
			Weighted normalized												
S1	0.232	0.201	0.097	0.189	0.233	0.230	0.204	0.222	0.215	0.038	0.129	0.196	0.225	0.091	0.258
S2	0.180	0.201	0.097	0.135	0.167	0.165	0.204	0.222	0.129	0.023	0.129	0.118	0.135	0.091	0.184
S3	0.129	0.144	0.058	0.081	0.033	0.099	0.087	0.044	0.043	0.008	0.078	0.118	0.135	0.054	0.037
S4	0.180	0.201	0.097	0.189	0.167	0.165	0.146	0.133	0.129	0.038	0.078	0.196	0.225	0.127	0.110
S5	0.129	0.086	0.135	0.135	0.100	0.165	0.087	0.133	0.043	0.008	0.078	0.196	0.135	0.054	0.110
			Values of (f^*)-f_{jn}												
S1	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
S2	0.05	0.00	0.04	0.05	0.07	0.07	0.00	0.00	0.09	0.02	0.00	0.08	0.05	0.00	0.04
S3	0.10	0.06	0.08	0.11	0.20	0.13	0.12	0.18	0.17	0.03	0.05	0.08	0.10	0.06	0.08
S4	0.05	0.00	0.04	0.00	0.07	0.07	0.06	0.09	0.09	0.00	0.05	0.00	0.05	0.00	0.04
S5	0.10	0.12	0.00	0.05	0.13	0.07	0.12	0.09	0.17	0.03	0.05	0.00	0.10	0.12	0.00
			Values of $w_n*(((f^*)-f_{jn})/(f^*)-(f-))$												
S1	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
S2	0.20	0.00	0.11	0.17	0.12	0.19	0.00	0.00	0.14	0.03	0.00	0.38	0.39	0.10	0.12
S3	0.39	0.19	0.22	0.34	0.35	0.38	0.35	0.37	0.29	0.06	0.23	0.38	0.39	0.20	0.36
S4	0.20	0.00	0.11	0.00	0.12	0.19	0.17	0.18	0.14	0.00	0.23	0.00	0.00	0.00	0.24
S5	0.39	0.39	0.00	0.17	0.23	0.19	0.35	0.18	0.29	0.06	0.23	0.00	0.39	0.20	0.24

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