Environment, Development and Sustainability
https://doi.org/10.1007/s10668-021-01675-8

# Identifying critical failure factors of green supply chain management in China's SMEs with a hierarchical cause–effect model

**Shuo Gao[1] · Ming Kim Lim[2] · Renlu Qiao[3] · Chensi Shen[4] · Chentao Li[5] · Li Xia[6]**

Received: 9 February 2021 / Accepted: 19 July 2021


**Abstract**
Compared to large companies, the small and medium enterprises (SMEs) in China are more likely to fail in developing green supply chain management (GSCM). Capturing its failure factors could be useful for managers and policymakers to decide how green supply chains can be successfully designed and developed. Meanwhile, these factors can include complex interrelationships. Properly dealing with them can help identify the critical factors which can assist decision-makers to efficiently manage green supply chains. This study thus proposes a comprehensive framework to explore and understand failure factors of GSCM in China's SMEs to improve the opportunities of GSCM in China. The fuzzy synthetic evaluation (FSE) and decision-making trial and evaluation laboratory (DEMATEL) are combined and applied to identify critical failure factors through translating interrelationships in a hierarchical cause–effect model. The results indicate that collaboration and support are the most critical perspectives for GSCM, and these two perspectives also interrelated with each other and affect the perspectives of knowledge, technology and economy to varying degrees. Moreover, the critical failure factors include lack of top management support, poor guidance from authorities, difficulty in supplier selection and inadequate supplier commitment. Sensitivity analysis is conducted to check the robustness. Conceptual and managerial implications are discussed.

**Keywords** Supply chain management · Environmental management · Decision-making · Business · Fuzzy set theory

## 1 Introduction

Since the United Nation announced its 2030 sustainable development goals, an increasing number of countries and industries are endeavouring to accomplish them (Wu et al., 2019a). China has experienced a rapid economic development during the past decades, leading to diverse conflicts between industry and the environment (Li et al., 2021). SMEs are an important impetus to its economic growth, but under China's

✉ Li Xia
lxia1118@mail.ustc.edu.cn

Extended author information available on the last page of the article

Published online: 28 July 2021

environmental targets set in its recently published 14th five-year plan they are currently facing considerable burdens to pursue corporate sustainable development (Stern & Xie, 2020). The SMEs have been expected to develop more sustainable business strategies to reduce the adverse environmental impacts, one of which is to integrate a green concept into their supply chain management and reduce their impacts along the supply chain on the environment and society (Tseng et al., 2019a). Therefore, the concept of green supply chain management (GSCM) has been coined as a tool to implement supply chain management practices with environmental or/and ecological concerns (Tseng et al., 2019a). GSCM covers the management from the very beginning part of the supply chain, procurement and purchasing, to environmental management practices related to all the stakeholders in the supply chain, including the suppliers, manufacturers, retailers and customers, to reverse logistics by which the supply chain loop can be closed (Zhu & Sarkis, 2004). It has been verified that GSCM can increase synergy and efficiency, enhance environmental performance, reduce environmental impacts and risks and cut costs to increase profits (Govindan et al., 2014).

However, the capacity of GSCM can be determined by the firm size. Though China has been providing political and financial support for circular production patterns and green supply chains in the industry, large companies are more likely to obtain this support, who already own comparatively more resources to introduce GSCM, while the SMEs normally gain less support from the authorities, though they themselves have less relevant information, experience and expertise, and fewer resources (Govindan et al., 2014). Thus, many SMEs fail to employ or sustain GSCM (Wooi & Zailani, 2010). Learning from these failure factors is essential for solving this issue (Wang & Wu, 2017). Nevertheless, previous studies normally investigated into the success factors of GSCM (Agi & Nishant, 2017; Gandhi et al., 2016; Mumtaz et al., 2018); though some studies have considered failure factors of supply chain management, they rarely entailed "green" (Cui et al., 2019). Besides, to our knowledge, there is no study investigating factors that hamper GSCM in the setting of China. Thus, this paper aims to focus on the failure factors of GSCM in China's SMEs to fill in the research gap.

This paper develops and uses a hybrid decision-making tool to reach this research aim. Based on the fuzzy logic, FSE is a handy approach to translate the complicated interrelationships into a hierarchical framework while taking multiple perspectives into account (Gautam & Nagendra, 2018). It is a time-saving tool that can aggregate experts' respondents and transform them into an intermediate stage that is easier to be integrated with other approaches. To identify critical failure or success factors, many previous studies identify the causal relationships among them, and the DEMATEL approach is commonly applied to visualize these interrelationships. To solve the GSCM's critical factor issue, this study integrates FSE with DEMATEL with the purpose of collecting linguistic preference relations from experts, and reflecting the causal relationships among factors in the framework.

Therefore, this study attempts to achieve the following research objectives: (i) investigating the failure factors to support policymakers and managers to promote GSCM for a better climate that accelerate SMEs' sustainability transformation; (ii) identifying critical failure factors for China's SMEs for more efficient decision-making; (iii) addressing the interrelationship among the attributes with a cause–effect model established by the hybrid FSE-DEMATEL method.

## 2 Literature review

This section reviews the literature related to small and medium enterprises in China, green supply chain management and its failure factors, and the proposed method. The last part of this section highlights the research gap.

### 2.1 Small and medium enterprises in China

The Chinese government has launched national projects, including the circular economy project in 2005 and supply chain innovation project in 2018, and selected a set of pilot companies, normally large companies, and provided support and guidance on their green business development. While these large companies demonstrate high resource efficiency and environmental performance in their supply chains after years of promotion, many SMEs have barely improved (Wu et al., 2019a). Though the SMEs individually may have very small impact on the environment, their collective impact can be significant since they take a huge part in the Chinese economy (Mathiyazhagan et al., 2013). Promoting green development in the SMEs can help meet the green growth goal of the national economy and may potentially benefit themselves from cost and risk reduction, resource sustainability, product differentiation, competitive advantages and investment return (Duber-Smith, 2005; Mathiyazhagan et al., 2013).

Besides the fact that SMEs in China get less support from the government compared to the large companies, they per se own less information, expertise and experience for building green business strategies; they have fewer resources, namely money, technique, time, relational capital and opportunities, and are more likely to have dictator bosses (Govindan et al., 2014). When these SMEs manage supply chain issues, they may also face difficulties in encouraging the upstream suppliers to operate greenly because the suppliers often need to invest in more resources to achieve that (Arimura et al., 2011). Therefore, SMEs could fail to implement GSCM due to diverse factors. This study will then investigate the failure factors to support decision-makers to make useful changes for a better environment that transforms traditional businesses (Wang & Wu, 2017).

### 2.2 Green supply chain management and its failure factors

GSCM refers to the management of resources, materials, components, processes while considering all the environmental impacts on the stakeholders throughout the supply chain (Hu & Hsu, 2010). It enables companies to meet the government's requirement, reduce environment-related risks and negative impacts, promote corporate social reputation and improve competitiveness and boost sales. Many previous studies have identified important GSCM practices and success factors. For example, Hu and Hsu et al. (2010) developed a framework and applied exploratory factor analysis to identify core factors for GSCM implementation. Govindan et al. (2014) identified barriers for GSCM in the Indian industries using analytic hierarchy process. Gandhi et al. (2016) combined analytic hierarchy process and DEMATEL to evaluate the success factors of GSCM for the Indian manufacturing industry. Luthra et al. (2016) collected data from 123 Indian automobile companies to examine the impacts of critical success factors for performing GSCM. Gao et al. (2021) drew on corporate website information and qualitative assessment data to benchmark GSCM practices in the chemical industry of China. However, to the best of our knowledge, the case of studying the failure factors concerning GSCM in the context of China's SMEs is still lacking in the existing literature. This study thus provides a framework for companies to understand key failure factors of GSCM in order to improve the opportunities of GSCM in parallel to the research working on the success factors and practices.

The failure of GSCM can be attributed to economic factors (P1), since high costs and lack of financial resources can impede success of related environmental actions (Zhang et al., 2009). Financial constraints (C1) can be a dominant failure factor because many SMEs have inadequate budget allocations to employ GSCM (AlKhidir & Zailani, 2009; Tseng et al., 2019a). The paths of SMEs seeking for financial supports may be blocked because of the non-availability of bank loans (C2) regarding GSCM initiatives (Govindan et al., 2014). Compared to the companies in many developed countries, it is way harder for the SMEs to get loan in China regarding green initiatives. Also, though companies implementing recycling and waste management could benefit economically and environmentally through enhancing resource efficiency and reducing pollution, the cost of recycling and waste management (C3) can be too high to afford for SMEs. This factor is important because many small companies are reluctant to develop GSCM simply because managing the industrial wastes means an increase of costs in the short run. Moreover, companies must have adequate human resources (C4) as GSCM practitioners (Perron, 2005). This indicates companies might fail in GSCM because of the lack of well-trained engineers or managers, or training for the incumbent managers and workers for GSCM implementation.

Moreover, GSCM may fail technologically (P2); greening the processes and products must rely on the support of green technology (Govindan et al., 2014), and GSCM sometimes requires the employment and updates of more advanced technology (Mudgal et al., 2010). Insufficient technical specialists (C5) can be a failure factor since promoting technical solutions to GSCM and supporting other relevant requirements need the consultancy within the area of specialism. Moreover, many companies fail to carry out eco-design (C6), thereby failing in GSCM (Govindan et al., 2014; Perron, 2005; Revell & Rutherfoord, 2003); eco-design refers to the industrial design for reducing the consumption of unsustainable materials, and minimization of the adverse effects on the environment, which has been regarded as an indispensable procedure for GSCM (Hu & Hsu, 2010). In addition, the negligence of new technology (C7), including new materials and processes, can bring about failure in minimizing the environmental damages and thus lead to GSCM failure (Perron, 2005).

Furthermore, SMEs can meet difficulty in collaboration (P3) (Arimura et al., 2011). This perspective is vital because successful GSCM practices require the collaboration with suppliers to develop joint strategies, purchase eco-friendly products and work towards cleaner production (Chin et al., 2015a, 2015b) One of the underlying failure reasons can be the partnerships with suppliers being difficult to build up with environment awareness (Tseng et al., 2019a; Wolf & Seuring, 2010). SMEs normally have fewer environmental partners (C8) compared to the large companies. Also, if suppliers are reluctant to make environmental commitment or exchange information for GSCM(C9), collaboration will also collapse (Sarkis, 2003); it will not be achieved if the companies and their suppliers are not constructively sharing, exchanging and studying useful knowledge. In fact, suppliers would not be fully committed to GSCM and willing to exchange relevant information with the companies unless they have already built deep trust and forged strong bonds. Furthermore, it can be difficult for companies to select green suppliers (C10) (Govindan et al., 2014). Lack of consideration of GSCM criteria or applying incomplete or unsystematic criteria to select supplier can to some extent lead to failure of GSCM (Tseng et al., 2019a).

Lack of knowledge can also bring about GSCM failure (Björklund et al., 2012). The corporate knowledge (P4) for GSCM consists of two parts: (1) explicit knowledge that can be expressed, documented and shared with stakeholders and employees for promoting GSCM (e.g. environmental laws and regulations); (2) tacit knowledge which is difficult to express and transfer (e.g. environmental awareness and belief). Specifically, SMEs without environmental awareness and belief in environmental benefits (C11) may not treat GSCM seriously (Mudgal et al., 2010; Walker et al., 2008). This factor can cause failure in an implicit way while this kind of disbelief and negligence is very difficult to be altered within a short period of time. Also, failure can come from the lack of latest environmental knowledge (C12), including the latest environmental policies (Shen & Tam, 2002; Tseng et al., 2019a); losing track of the changes of relevant policies can cause delay in or even inaction of corporate responses to them. Moreover, companies need to set organizational goals (C13) with specific outcomes which the companies commit to attain to achieve GSCM (Theyel, 2000). Unclear, indefinite or uncertain goals for GSCM without clearly defining requirements, mapping out the route and establishing roles can be a key factor that causes its failure.

For practicing any business strategy including the GSCM, management support (P5) is always essential (Mudgal et al., 2010). Support can be obtained internally or externally, yet problems can arise from both aspects for China's SMEs. Support and guidance from the authorities (C14) are often important for the employment or sustainment of GSCM (Perron, 2005). In China, large companies are prone to be supported, but SMEs are not, which might be a key reason why many SMEs fail to initiate it. Moreover, poor management capacity (C15) can lead to failure since insufficient volume of work is carried out to support GSCM (Govindan et al., 2014). Additionally, if industrial practitioners are unable to take training programs (C16), they may not be able to successfully enact GSCM in their units of the industry (Carter & Dresner, 2001). The training programs should be developed to help companies incorporate green concepts into their supply chain management systems and offer support for the GSCM work placement and actions. Lastly, resistance from the top executives (C17) to make changes will hinder the progress of GSCM (Emiliani, 2010; Hu & Hsu, 2010; Mathiyazhagan et al., 2013; Zhu et al., 2007). Many SMEs could be family businesses and are likely to have dictator bosses (Govindan et al., 2014). When some top managers fail to change their mindsets and value the corporate responsibilities for designing green supply chains, the mid-level managers and practitioners will definitely not earnestly implement the GSCM practices. Therefore, five perspectives and seventeen failure factors are proposed for evaluation as shown in Table 1.

### 2.3 Proposed method

Assessing and identifying key failure factors in a real-world issue can be a complex and ambiguous process. The opinions from the experts contain subjective and uncertain information. The fuzzy set theory addresses the issue of subjective, imprecise and ambiguous judgement (Wu et al., 2019a). Based on the theory, fuzzy synthetic evaluation (FSE) was developed to express and evaluate the fuzzy attributes based on experts' linguistic preference relations and address the interdependent relationships among attributes and convert them into a hierarchical framework (Gautam & Nagendra, 2018; Tseng et al. 2019b). FSE was widely applied in research fields as diverse as risk management, supply chain management and sustainability. For instance, Zhao et al. (2019) integrated FSE with health risk assessment to evaluate heavy metals in Zhangye agricultural soil. Wu et al. (2019b) used FSE to assess the potential risk factors for China's electric vehicle supply chain under uncertainty. Wu et al. (2019c) proposed a hybrid method that combined FSE and the analytical network process to bridge

**Table 1** Proposed perspectives and criteria

| Perspectives | | Criteria | | Reference |
|---|---|---|---|---|
| P1 | Economy | C1 | Financial constraints | AlKhidir & Zailani (2009), Tseng et al. (2019a) |
| | | C2 | Non-availability of bank loans | Govindan et al. (2014) |
| | | C3 | Cost of recycling and waste management | Author's experience |
| | | C4 | Lack of human resources | Perron (2005) |
| P2 | Technology | C5 | Lack of technical specialists | Revell and Rutherfoord (2003), Perron (2005) |
| | | C6 | Difficulty in eco-design | Govindan et al. (2014), Perron (2005) |
| | | C7 | Lack of new technology | Perron (2005) |
| P3 | Collaboration | C8 | Lack of environmental partners | Tseng et al. (2019a), Wolf & Seuring (2010) |
| | | C9 | Inadequate supplier commitment | Sarkis (2003) |
| | | C10 | Difficulty in supplier selection | Govindan et al. (2014) |
| P4 | Knowledge | C11 | Lack of environmental awareness and belief in environmental benefits | Mudgal et al. (2010), Walker et al. (2008) |
| | | C12 | Lack of latest environmental knowledge | Shen and Tam (2002), Tseng et al. (2019a) |
| | | C13 | Lack of organizational goals | Theyel (2000) |
| P5 | Support | C14 | Poor guidance from authorities | Perron (2005) |
| | | C15 | Unstable management capacity | Govindan et al. (2014) |
| | | C16 | Non-availability of training programs | Carter and Dresner (2001) |
| | | C17 | Lack of top management support | Mathiyazhagan et al. (2013), Zhu et al. (2007) |

knowledge management with corporate sustainability. The previous literature suggests FSE can be applied to present a reliable evaluation tool dealing with interdependent decision-making issues under ambiguous circumstances. These studies also demonstrate that FSE needs to be integrated with other decision analysis instrument for further factor analysis. A comparison among several widely applied decision-making tools, DEMATEL, interpretative structural modelling (ISM) and analytic hierarchy process (AHP), is presented in Table 2.

DEMATEL was developed by the Geneva Research Centre of the Battelle Memorial Institute to measure complex causality (Gabus & Fontela, 1972). It is now widely used as a group decision method identifying the cause–effect chains of a complicated real-world system (Si et al., 2018). It can effectively convert the causal relationships among attributes into different groups based on centrality and causality and visualize the cause–effect chains in an intertwined problem by developing a map that demonstrates the critical measures of a system via impact relation diagram. DEMATEL has been used to deal with many decision-making issues with respect to complexity and causality by a systematic evaluation (e.g. Lin, 2013; Govindan et al., 2014; Wu et al., 2015). For example, Cui et al. (2019) applied DEMATEL to depict a causal relationship diagram to analyse and explore the critical factors of business failure. Yazdi e al. (2020) integrated DEMATEL with best–worst method and Bayesian network and captured the strong interactions among risk factors to support decision-making for effective safety management. The integration of FSE and DEMATEL allows experts' evaluation opinions to finally arrive at visualized causal relationships.

Overall, given that FSE is a handy decision-making tool that collects preference relations and translates interrelationships into a hierarchical framework, and DEMATEL is capable of visualizing the causal relationships in a complex system, this study thus combined them in an attempt to achieve the following objectives: (i) collect respondents' evaluation data using a fuzzy scale; (ii) weigh the attributes while considering both of interdependent relationships and cause–effect chains; (iii) explore, visualize and identify critical attributes in a via impact relation diagram.

## 3 Research gap

Here we summarize the key gap that this paper attempts to solve. Since SMEs in China are way more likely to fail in GSCM than large companies, it is vital to understand their failure reasons to support decision-making processes, which have not yet been studied in the prior literature. From the resource-based view, identifying the critical and decisive factors can help the decision-makers manage the issue efficiently. Thus, to investigate the critical factors, an evaluation method is developed combining FSE and DEMATEL to investigate the interrelationships among attributes in the proposed evaluation structure and to virtualize experts' opinions in a direct impact diagram.

## 4 Methodology

Based on fuzzy set theory, the FSE is carried out to solve the problem with nondeterministic characteristics. FSE compares factors through a nonlinear integer-programming model. Based on digraphs, DEMATEL can show the directed relationships of the factors in a system. Suppose there are $n$ factors in a system $S$, $S = \left\{s_1, s_2 \cdots s_n\right\}$. The mathematical relation $R$ determines the pair-wise relationships. The entry demonstrates the extent to which the factor

**Table 2** DEMATEL, ISM and AHP. *Source* from Mumtaz et al., (2018), Agi and Nishant (2017), and Saaty (1980)

| Tool | DEMATEL | ISM | AHP |
|---|---|---|---|
| Description | DEMATEL reveals the causal relationship among attributes and can visualize it through mapping a cause–effect diagram | ISM is good at capturing and building hierarchical relationship among attributes by means of two dimensions, namely dependency and driving power | AHP assumes that attributes are independent, and does not consider feedback effect |

$s_i$ causes $s_j$ in the relation$R$. The initial direct relation matrix $M$ is obtained by all the comparisons between factors in the system $S$. The digraph depicts the contextual relation among the factors. The numeral demonstrates the strength of the influence. The proposed analytic flow is proposed in Fig. 1. The analytical procedures for this research are as follows.

### 4.1 FSE-DEMATEL

Suppose there are $r$ experts in the decision group who evaluate the performance of $f$ factors, and $\left[E_{ij}\right]_{r\times f}^{A_n}$ denotes the evaluation matrix under attribute $A_n$. Then, these panellists need to fill in pair-wise comparison questionnaires based on a five-point fuzzy synthetic scale, as shown in Table 2. After the relations are evaluated, these relations have to be transformed into corresponding fuzzy synthetic scales (see Table 2) for further computation.

With reference to Table 2, $E_{ij}$ should be rearranged through the following equation:

$$\left[E_{ij}\right]_{1\times 5} = \left[VL_{ij}, L_{ij}, M_{ij}, H_{ij}, VH_{ij}\right]_{1\times 5} \tag{1}$$

where $VL_{ij}, L_{ij}, M_{ij}, VH_{ij}$ and $H_{ij}$ are the transformed qualitative assessment for each attribute.

Subsequently, the corresponding frequency of $\left[E_{ij}^{A_n}\right]_{1\times 5}$ can be derived and normalized through adopting the following equation:

$$\left[E_{ij}^{A_n}\right]_{1\times 5} = \left[\frac{VL_{ij}}{r}, \frac{L_{ij}}{r}, \frac{M_{ij}}{r}, \frac{VH_{ij}}{r}, \frac{H_{ij}}{r}\right]_{1\times 5} \tag{2}$$

Then, the crisp values $\left[E_{ij}^{A_n}\right]$ can be extracted after normalization using the following equation:

$$E_{ij}^{A_n} = 1\times\frac{VL_{ij}}{r} + 2\times\frac{L_{ij}}{r} + 3\times\frac{M_{ij}}{r} + 4\times\frac{VH_{ij}}{r} + 5\times\frac{H_{ij}}{r} \tag{3}$$

Afterwards, the following equation is applied to generate the factor weights $\left[\overline{E}_{ij}^{A_n}\right]$:

$$\overline{E}_{ij}^{A_n} = \frac{E_{ij}^{A_n}}{\sum_{i=1}^{f} E_{ij}^{A_n}} \tag{4}$$

Then, the membership function of $A_n$ can be obtained through integrating factor weights with the initial scale $E_{ij}$:

$$\left[m\overline{E}_{ij}^{A_n}\right]_{k\times r} = \left[\overline{E}_{ij}^{A_n}\right]_{k\times f} \times \left[E_{ij}\right]_{f\times r} = \left[\hbar_{ij}^{A_n}\right]_{k\times r} = \left[\hbar_{ij}^{1A_n}, \hbar_{ij}^{2A_n}, \hbar_{ij}^{3A_n}, \hbar_{ij}^{4A_n}, \hbar_{ij}^{5A_n}\right] \tag{5}$$

Once acquiring the membership function of $A_n$, the value of membership function $m\overline{E}_{ij}^{A_n}$ is to be computed:

$$vm\overline{E}_{ij}^{A_n} = 1\times\hbar_{ij}^{1A_n} + 2\times\hbar_{ij}^{2A_n} + 3\times\hbar_{ij}^{3A_n} + 4\times\hbar_{ij}^{4A_n} + 5\times\hbar_{ij}^{5A_n} \tag{6}$$

The direct relation matrix $\forall$ is obtained through aggregating $vm\overline{E}_{ij}^{A_n}$, and $\forall$ need to be further normalized:

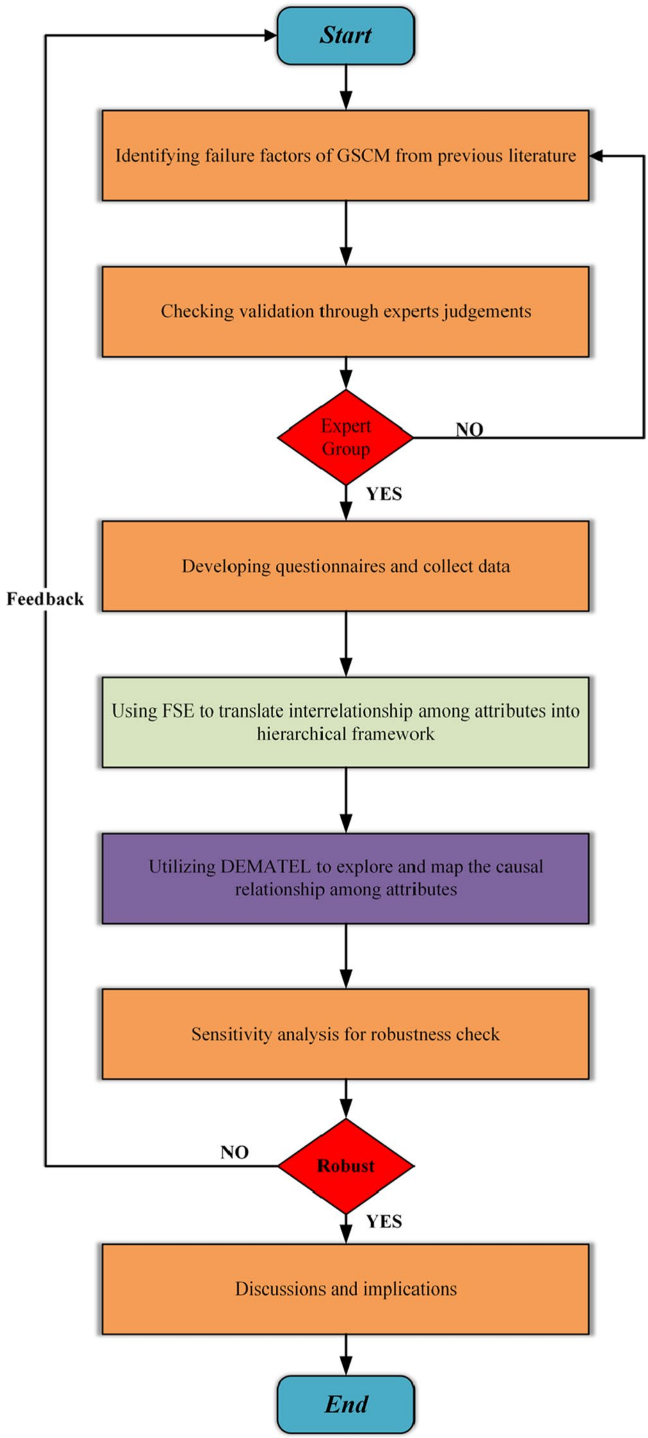



**Fig. 1** Analytical flowchart

$$\tilde{\forall} = \frac{vm\overline{E}_{ij}^{A_n}}{max\left[max\sum_{i=1}^{n} vm\overline{E}_{ij}^{A_n}, max\sum_{j=1}^{n} vm\overline{E}_{ij}^{A_n}\right]} \tag{7}$$

Thus, the total relation matrix $T$ is derived:

$$T = \tilde{\forall} + \tilde{\forall}^2 + \tilde{\forall}^3 + \cdots + \tilde{\forall}^{\varphi} = \tilde{\forall}\left(I - \tilde{\forall}\right)^{-1} = \left[\tau_{ij}\right]_{f\times f} \text{ when } \varphi \rightarrow \infty \tag{8}$$

where $I$ represents the identity matrix.

Finally, the sum of rows and the sum of columns within the total relation matrix $T$ are calculated via the following equations:

$$D = \left[\sum_{j=1}^{f} \tau_{ij}\right]_{1\times n} = \left(d_1, d_2, d_3, d_4, d_5\right) \tag{9}$$

$$R = \left[\sum_{i=1}^{f} \tau_{ij}\right]_{n\times 1} = \left(r_1, r_2, r_3, r_4, r_5\right) \tag{10}$$

where $D$ and $R$, respectively, represent the sum of rows and the sum of columns.

### 4.2 Data mapping for proposed criteria

A cause–effect diagram can be generated by mapping the dataset of $\left\{\forall i \in n | \left(d_i + r_i, d_i - r_i\right)\right\}$ on the coordinates. $(D + R)$ describes the degree of centrality while $(D - R)$ presents the degree of causality (Tseng et al., 2018), and this diagram is mapped using $\left(d_i + r_i\right)$ as the horizontal axis and $\left(d_i - r_i\right)$ as the vertical axis. The diagram can be divided into four sections that select driving attributes (high centrality and high causality), core attributes (high centrality but low causality), voluntary attributes (low centrality but high causality) and independent attributes (low centrality and low causality). The values of $\left(d_i + r_i, d_i - r_i\right)$ determine the category to which the attribute belongs.

### 4.3 Relationship identification for perspectives

To identify the relationships among $\alpha$ perspectives, this study adopts the geometric mean as the threshold value $\mu$ by employing the equation below in the corresponding relation matrix $T^{\alpha} = \left[t_{ij}^{\alpha}\right]_{\alpha\times\alpha}$:

$$\mu = \sqrt[\alpha^2]{\prod t_{ij}^{\alpha}} \tag{11}$$

Once $t_{ij}^{\alpha} > \mu$, it denotes there is a significant cause–effect relationship between the two perspectives; otherwise, the relationship is not significant. This identifies relationships are then classified into three groups: strong, medium and weak, according to the relative values of the relationship.

**Table 3** Fuzzy synthetic scales

| Linguistic preference relations | Corresponding fuzzy synthetic scales |
|---|---|
| Very low (VL) influence | 1 |
| Low (L) influence | 2 |
| Medium (M) influence | 3 |
| High (H) influence | 4 |
| Very high (VH) influence | 5 |

**Table 4** A sample of panellist evaluation of perspectives

| Evaluation | Before transformation | | | | | After transformation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P1 | P2 | P3 | P4 | P5 |
| P1 | VH | VL | H | M | H | 5 | 1 | 4 | 3 | 4 |
| P2 | L | VH | L | VH | VH | 2 | 5 | 2 | 5 | 5 |
| P3 | M | M | VH | VH | VL | 3 | 3 | 5 | 5 | 1 |
| P4 | VH | L | H | VH | M | 5 | 2 | 4 | 5 | 3 |
| P5 | VL | M | VH | L | VH | 1 | 3 | 5 | 2 | 5 |

## 5 Result

In this section, the analytical procedures and corresponding result of FSE-DEMATEL are presented step by step, as well as the sensitivity analysis.

(1) All the 21 experts that were interviewed came from universities, global NGOs, or have working on sustainability issues in the private sector for more than 5 years. The survey was taken anonymously, and most of the evaluation data were collected through online questionnaires, while two through telephone and one through face-to-face interview. A sample of respondent evaluation of the proposed perspectives is illustrated in Table 3. Therein, the left part of this table shows the untransformed result of respondent evaluation, and the right part presents the transformed respondent evaluation with reference to Table 4.

(2) Equations(1)–(6) were used to compute the membership function and corresponding crisp values of the criteria, as shown in Table 5. For instance, the crisp value of C3 under C1 (bolded line in Table 3) should be calculated as $vm\overline{E}_{ij}^{C_3} = 1 \times 0.10 + 2 \times 0.29 + 3 \times 0.19 + 4 \times 0.24 + 5 \times 0.19 = 3.14$. Afterwards, Eq. (7) was adopted to obtain the direct relation matrix of the proposed perspectives and criteria, which was, respectively, presented in Tables 6 and 7. Subsequently, the total relation matrix of the perspectives and criteria were derived by means of Eq. (8), as illustrated in Tables 8 and 9, respectively.

(3) Equations(9)–(10) were used to calculate the degree of centrality and the degree of causality with regard to 5 perspectives and 21 criteria, which were aggregated and shown in Table 10. Accordingly, the dataset $\left(d_i + r_i, d_i - r_i\right)$ could be acquired and thereby used to map the cause–effect diagrams in terms of perspectives and criteria. It could be found from the sixth column of Table 9; the cause factors include C1, C4, C9, C10, C11, C14, C15, C13, C17, and C2, C3, C5, C6, C7, C8, C12, C16, C18, C19,

**Table 5** Crisp value and membership function of the criteria

| | C1 | | | | | | C2 | | | | | | C3 | | | | | | C4 | | | | | | C17 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crisp Values | Membership function | | | | | Crisp Values | Membership function | | | | | Crisp Values | Membership function | | | | | Crisp Values | Membership function | | | | | Crisp Values | Membership function | | | | |
| C1 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.19 | 0.14 | 0.19 | 0.19 | 0.29 | 0.19 | 2.43 | 0.33 | 0.33 | 0.10 | 0.05 | 0.19 | 2.38 | 0.24 | 0.38 | 0.19 | 0.14 | 0.05 | 2.48 | 0.29 | 0.33 | 0.10 | 0.19 | 0.10 |
| C2 | 3.05 | 0.14 | 0.10 | 0.38 | 0.33 | 0.05 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 2.48 | 0.38 | 0.19 | 0.14 | 0.14 | 0.14 | 3.52 | 0.05 | 0.24 | 0.19 | 0.19 | 0.33 | 2.81 | 0.24 | 0.14 | 0.24 | 0.33 | 0.05 |
| C3 | 3.14 | 0.10 | 0.29 | 0.19 | 0.24 | 0.19 | 3.10 | 0.14 | 0.29 | 0.14 | 0.19 | 0.24 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 2.86 | 0.24 | 0.19 | 0.14 | 0.33 | 0.10 | 4.24 | 0.00 | 0.19 | 0.05 | 0.10 | 0.67 |
| C4 | 3.19 | 0.10 | 0.10 | 0.43 | 0.29 | 0.10 | 3.43 | 0.05 | 0.14 | 0.33 | 0.29 | 0.19 | 3.24 | 0.10 | 0.14 | 0.24 | 0.48 | 0.05 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.14 | 0.24 | 0.19 | 0.05 | 0.24 | 0.29 |
| C5 | 3.05 | 0.10 | 0.33 | 0.14 | 0.29 | 0.14 | 3.05 | 0.05 | 0.33 | 0.24 | 0.29 | 0.10 | 2.81 | 0.14 | 0.24 | 0.29 | 0.33 | 0.00 | 3.24 | 0.05 | 0.24 | 0.29 | 0.29 | 0.14 | 2.43 | 0.38 | 0.19 | 0.14 | 0.19 | 0.10 |
| C6 | 2.67 | 0.19 | 0.24 | 0.38 | 0.10 | 0.10 | 3.52 | 0.05 | 0.19 | 0.19 | 0.33 | 0.24 | 3.43 | 0.10 | 0.29 | 0.05 | 0.24 | 0.33 | 2.71 | 0.24 | 0.19 | 0.29 | 0.19 | 0.10 | 2.62 | 0.24 | 0.29 | 0.24 | 0.10 | 0.14 |
| C7 | 3.76 | 0.00 | 0.14 | 0.29 | 0.24 | 0.33 | 3.67 | 0.05 | 0.10 | 0.24 | 0.38 | 0.24 | 3.33 | 0.19 | 0.14 | 0.10 | 0.29 | 0.29 | 2.48 | 0.24 | 0.24 | 0.33 | 0.19 | 0.00 | 2.62 | 0.33 | 0.19 | 0.14 | 0.19 | 0.14 |
| C8 | 2.90 | 0.05 | 0.24 | 0.52 | 0.14 | 0.05 | 3.05 | 0.19 | 0.14 | 0.29 | 0.19 | 0.19 | 3.10 | 0.05 | 0.33 | 0.24 | 0.24 | 0.14 | 3.24 | 0.10 | 0.14 | 0.33 | 0.29 | 0.14 | 2.67 | 0.24 | 0.24 | 0.24 | 0.19 | 0.10 |
| C9 | 3.29 | 0.05 | 0.19 | 0.38 | 0.19 | 0.19 | 3.24 | 0.10 | 0.24 | 0.24 | 0.19 | 0.24 | 3.33 | 0.10 | 0.19 | 0.24 | 0.24 | 0.24 | 3.33 | 0.19 | 0.19 | 0.10 | 0.14 | 0.38 | 3.71 | 0.10 | 0.05 | 0.24 | 0.29 | 0.33 |
| C10 | 3.29 | 0.05 | 0.19 | 0.33 | 0.29 | 0.14 | 3.33 | 0.10 | 0.24 | 0.19 | 0.19 | 0.29 | 3.52 | 0.10 | 0.24 | 0.14 | 0.10 | 0.43 | 3.29 | 0.10 | 0.19 | 0.24 | 0.29 | 0.19 | 2.57 | 0.29 | 0.29 | 0.19 | 0.05 | 0.19 |
| C11 | 2.62 | 0.14 | 0.48 | 0.10 | 0.19 | 0.10 | 2.71 | 0.19 | 0.29 | 0.24 | 0.19 | 0.10 | 4.14 | 0.00 | 0.10 | 0.14 | 0.29 | 0.48 | 3.33 | 0.19 | 0.05 | 0.14 | 0.48 | 0.14 | 3.62 | 0.10 | 0.05 | 0.33 | 0.19 | 0.33 |
| C12 | 2.86 | 0.19 | 0.29 | 0.19 | 0.14 | 0.19 | 3.10 | 0.05 | 0.33 | 0.24 | 0.24 | 0.14 | 3.33 | 0.14 | 0.19 | 0.10 | 0.33 | 0.24 | 2.86 | 0.29 | 0.19 | 0.10 | 0.24 | 0.19 | 3.05 | 0.10 | 0.33 | 0.19 | 0.19 | 0.19 |
| C13 | 2.62 | 0.24 | 0.29 | 0.14 | 0.29 | 0.05 | 3.10 | 0.10 | 0.24 | 0.33 | 0.14 | 0.19 | 4.48 | 0.00 | 0.05 | 0.10 | 0.19 | 0.67 | 2.86 | 0.19 | 0.33 | 0.05 | 0.29 | 0.14 | 3.38 | 0.14 | 0.24 | 0.10 | 0.14 | 0.38 |
| C14 | 2.67 | 0.14 | 0.43 | 0.14 | 0.19 | 0.10 | 3.33 | 0.14 | 0.14 | 0.14 | 0.38 | 0.19 | 3.33 | 0.14 | 0.14 | 0.19 | 0.29 | 0.24 | 3.48 | 0.05 | 0.24 | 0.19 | 0.24 | 0.29 | 4.48 | 0.00 | 0.00 | 0.14 | 0.24 | 0.62 |
| C15 | 3.95 | 0.00 | 0.14 | 0.24 | 0.14 | 0.48 | 4.00 | 0.10 | 0.10 | 0.05 | 0.24 | 0.52 | 2.81 | 0.14 | 0.33 | 0.14 | 0.33 | 0.05 | 2.81 | 0.10 | 0.33 | 0.33 | 0.14 | 0.10 | 3.24 | 0.14 | 0.19 | 0.14 | 0.33 | 0.19 |
| C16 | 3.52 | 0.05 | 0.24 | 0.14 | 0.29 | 0.29 | 3.62 | 0.05 | 0.19 | 0.24 | 0.14 | 0.38 | 2.86 | 0.19 | 0.29 | 0.19 | 0.14 | 0.19 | 2.62 | 0.24 | 0.29 | 0.10 | 0.38 | 0.00 | 2.81 | 0.24 | 0.24 | 0.19 | 0.14 | 0.19 |
| C17 | 3.14 | 0.10 | 0.33 | 0.10 | 0.29 | 0.19 | 2.95 | 0.10 | 0.29 | 0.33 | 0.14 | 0.14 | 3.19 | 0.19 | 0.19 | 0.10 | 0.29 | 0.24 | 2.76 | 0.10 | 0.38 | 0.24 | 0.24 | 0.05 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |

**Table 6** Direct relation matrix of perspectives

| | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| P1 | 5.000 | 2.952 | 2.952 | 3.143 | 3.095 |
| P2 | 3.048 | 5.000 | 2.762 | 3.048 | 3.476 |
| P3 | 3.048 | 4.000 | 5.000 | 3.238 | 3.762 |
| P4 | 3.381 | 3.476 | 3.048 | 5.000 | 2.905 |
| P5 | 3.619 | 3.476 | 3.762 | 3.286 | 5.000 |

C20, C21 consist of the effect ones. Then, Fig. 2 depicts the corresponding cause–effect diagram of these criteria, and apparently, the most critical failure factors are identified as follows: lack of top management support (C17), poor guidance from authorities (C14), difficulty in supplier selection (C10) and inadequate supplier commitment (C9).

(4) Among the 5 perspectives, the sixth column of Table 9 shows that P3, P4, P5 belong to the cause group while P1 and P2 to the effect group. Afterwards, the causal relationships among them in terms of strong, medium and weak degree were explored. Threshold value $\mu = 3.413$ is computed through Eq. (11). Finally, it is identified that the collaboration (P3) and support (P5) interrelated with one another and can further affect the perspectives of knowledge (P4), technology (P2) and economy (P1) to varying degrees (Fig. 3).

(5) In order to check the robustness of the above-obtained results, this study specifically altered the initial assessment of [P4, C16] = [3, 3] to conduct a sensitivity analysis. Furthermore, two extreme situations were considered: the values of P4 and C16 were replaced as [P4, C16] = [1, 1] and [P4, C16] = [5, 5], respectively, and the results of each perturbation are presented in Fig. 4 and 5. Overall, these obtained results are unchanged except for C1 falling down from the cause group to the effect group. The robustness of the analytical results is thus good.

# 6 Discussion

## 6.1 Conceptual Implications

The study identifies the casual relationships among the attributes in the proposed structure based on experts' evaluation. As shown in Fig. 3, the results demonstrate that collaboration (P3) and support (P5) are the most critical perspectives for GSCM. This indicates the failure mainly come from the lack of involvement, support and collaboration. Besides, the cause–effect model shows the perspectives of collaboration and support interrelated with one another and can affect the perspectives of knowledge (P4), technology (P2) and economy (P1) to varying degrees. Therein, the medium effect of collaboration on economy can be partly confirmed by research by Chin et al. (2015a, 2015b). This implies without adequate management and governmental support as well as supplier collaboration, it can be difficult to get enough economic resources, technology transfer and utilization, and enough business knowledge for developing GSCM.

In addition, the results indicate that GSCM-related knowledge (P4) can influence the utilization and advancement of relevant technology (P2) in the company, which is in line with Spanellis et al. (2020). It implies the knowledge regarding environmental regulations and impacts, environmental awareness and belief in environmental benefits

**Table 7** Direct relation matrix of criteria

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 5.000 | 3.190 | 2.429 | 2.381 | 3.286 | 3.143 | 3.381 | 3.238 | 3.857 | 3.143 | 3.095 | 3.190 | 2.952 | 3.048 | 3.619 | 3.476 | 2.476 |
| C2 | 3.048 | 5.000 | 2.476 | 3.524 | 2.952 | 3.143 | 2.905 | 2.810 | 3.238 | 2.667 | 2.571 | 3.190 | 2.857 | 3.333 | 2.476 | 2.952 | 2.810 |
| C3 | 3.143 | 3.095 | 5.000 | 2.857 | 3.143 | 3.286 | 2.762 | 2.762 | 3.429 | 2.381 | 2.667 | 3.095 | 2.619 | 3.429 | 2.810 | 3.095 | 4.238 |
| C4 | 3.190 | 3.429 | 3.238 | 5.000 | 3.143 | 2.952 | 2.762 | 3.190 | 3.619 | 3.429 | 2.667 | 3.000 | 2.905 | 3.238 | 3.190 | 3.952 | 3.143 |
| C5 | 3.048 | 3.048 | 2.810 | 3.238 | 5.000 | 3.048 | 3.762 | 2.810 | 3.429 | 3.048 | 2.952 | 3.238 | 3.190 | 2.667 | 3.048 | 3.000 | 2.429 |
| C6 | 2.667 | 3.524 | 3.429 | 2.714 | 2.714 | 5.000 | 2.905 | 3.619 | 3.143 | 3.619 | 3.381 | 3.048 | 3.286 | 3.429 | 3.429 | 3.429 | 2.619 |
| C7 | 3.762 | 3.667 | 3.333 | 2.476 | 2.619 | 3.286 | 5.000 | 3.810 | 3.190 | 2.857 | 3.000 | 3.619 | 3.238 | 2.714 | 2.905 | 3.000 | 2.619 |
| C8 | 2.905 | 3.048 | 3.095 | 3.238 | 2.905 | 3.667 | 3.571 | 5.000 | 3.143 | 3.190 | 3.190 | 2.810 | 2.857 | 2.810 | 3.381 | 3.000 | 2.667 |
| C9 | 3.286 | 3.238 | 3.333 | 3.333 | 3.571 | 4.000 | 3.381 | 3.190 | 5.000 | 3.810 | 2.810 | 2.857 | 2.714 | 2.381 | 2.476 | 4.048 | 3.714 |
| C10 | 3.286 | 3.333 | 3.524 | 3.286 | 3.190 | 3.095 | 3.476 | 2.905 | 3.095 | 5.000 | 3.524 | 3.190 | 2.714 | 4.048 | 3.095 | 4.095 | 2.571 |
| C11 | 2.619 | 2.714 | 4.143 | 3.333 | 3.000 | 3.429 | 3.095 | 2.810 | 2.810 | 3.048 | 5.000 | 3.619 | 3.286 | 3.619 | 3.571 | 2.524 | 3.619 |
| C12 | 2.857 | 3.095 | 3.333 | 2.857 | 2.857 | 3.286 | 2.714 | 2.762 | 2.762 | 3.333 | 2.810 | 5.000 | 2.952 | 3.238 | 3.095 | 3.190 | 3.048 |
| C13 | 2.619 | 3.095 | 4.476 | 2.857 | 4.095 | 2.619 | 2.905 | 3.143 | 2.571 | 2.905 | 2.524 | 3.571 | 5.000 | 3.429 | 3.286 | 2.905 | 3.381 |
| C14 | 2.667 | 3.333 | 3.333 | 3.476 | 3.000 | 2.952 | 3.810 | 3.714 | 3.143 | 3.286 | 3.952 | 3.048 | 2.333 | 5.000 | 2.333 | 3.952 | 4.476 |
| C15 | 3.952 | 4.000 | 2.810 | 2.810 | 2.905 | 3.190 | 2.905 | 2.952 | 2.333 | 2.857 | 3.429 | 3.286 | 3.381 | 2.333 | 5.000 | 3.286 | 3.238 |
| C16 | 3.524 | 3.619 | 2.857 | 2.619 | 3.333 | 3.048 | 3.571 | 2.952 | 2.762 | 2.762 | 2.905 | 3.095 | 3.524 | 3.000 | 2.429 | 5.000 | 2.810 |
| C17 | 3.143 | 2.952 | 3.190 | 2.762 | 3.810 | 3.143 | 3.762 | 3.238 | 3.286 | 3.000 | 4.286 | 3.524 | 3.000 | 3.714 | 3.190 | 3.190 | 5.000 |

**Table 8** Total relation matrix of perspectives

| | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| P1 | 3.314 | 3.338 | 3.087 | 3.135 | 3.230 |
| P2 | 3.241 | 3.499 | 3.114 | 3.168 | 3.294 |
| P3 | 3.577 | 3.800 | 3.570 | 3.509 | 3.653 |
| P4 | 3.344 | 3.500 | 3.210 | 3.362 | 3.342 |
| P5 | 3.629 | 3.784 | 3.517 | 3.528 | 3.738 |

can potentially bring about application of advanced green technology and expertise in businesses to resolve GSCM issues. The results also prove that business strategy regarding economy (P1) exhibits no mediation, which could support the findings of Wijethilake (2017) and Tseng et al. (2018). This suggests the support and collaboration for GSCM should finally lead to the prevention of GSCM failure deal to economic reasons. Supply chain collaboration can lower the transaction and operational costs of GSCM than acting alone. Support from the top managers can internally help deal with the financial constraints and the scarcity of human resources in the companies.

### 6.2 Policy implications

Poor guidance from authorities (C14) is a critical failure factor of GSCM in the SMEs. Apparently, big companies in China are normally prioritized by the government and provide intensive support and guidance for their green supply chain actions. Though under the command from the central government, many local governments, such as Dongguan of Guangdong Province, have introduced encouraging policies with financial incentives for fostering GSCM in SMEs, they still fail to provide precise guidance to achieve this. Thus, besides the fact that the governments continue to positively provide subsidies, reduce tax or other economic incentive policies for these SMEs practicing GSCM and offer loan guarantees when needed, they still need give clearer guidance and make GSCM policy messages more accurate. Also, authorities should attempt to give industry-specific guidance, since different products in different industries may need to follow more accurate instruction.

Additionally, government procurement could also be a manner to support the SMEs develop GSCM. Though China's Ministry of Finance has released the regulation paper *Measures for the Administration of Government Procurement to Promote the Development of SMEs* at the end of 2020, the paper fails to mention any environmental standards that products or services need to obey. The government may still need to more carefully integrate its national green development principles into the public procurement policies to encourage China's SMEs to meet more GSCM requirements in order to provide products or services to the public sector.

### 6.3 Managerial implications

Mumtaz et al. (2018) sought factors that determine successful GSCM implementation and found that the eco-design and top management support are cause factors while supplier

**Table 9** Total relation matrix of criteria

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 1.124 | 1.144 | 1.117 | 1.038 | 1.108 | 1.122 | 1.134 | 1.096 | 1.106 | 1.082 | 1.090 | 1.124 | 1.050 | 1.102 | 1.071 | 1.162 | 1.080 |
| C2 | 1.032 | 1.116 | 1.059 | 1.005 | 1.044 | 1.063 | 1.066 | 1.032 | 1.038 | 1.018 | 1.024 | 1.065 | 0.994 | 1.051 | 0.995 | 1.092 | 1.030 |
| C3 | 1.071 | 1.121 | 1.142 | 1.028 | 1.086 | 1.104 | 1.102 | 1.068 | 1.079 | 1.049 | 1.063 | 1.102 | 1.025 | 1.090 | 1.037 | 1.134 | 1.094 |
| C4 | 1.115 | 1.172 | 1.155 | 1.107 | 1.128 | 1.142 | 1.146 | 1.118 | 1.124 | 1.110 | 1.105 | 1.143 | 1.071 | 1.129 | 1.084 | 1.195 | 1.116 |
| C5 | 1.067 | 1.118 | 1.101 | 1.032 | 1.115 | 1.097 | 1.117 | 1.066 | 1.076 | 1.058 | 1.065 | 1.102 | 1.033 | 1.073 | 1.038 | 1.129 | 1.057 |
| C6 | 1.103 | 1.171 | 1.157 | 1.064 | 1.118 | 1.176 | 1.146 | 1.124 | 1.113 | 1.111 | 1.116 | 1.142 | 1.076 | 1.131 | 1.087 | 1.183 | 1.104 |
| C7 | 1.104 | 1.155 | 1.135 | 1.042 | 1.098 | 1.127 | 1.164 | 1.109 | 1.096 | 1.079 | 1.090 | 1.134 | 1.057 | 1.099 | 1.060 | 1.155 | 1.085 |
| C8 | 1.079 | 1.133 | 1.121 | 1.046 | 1.093 | 1.124 | 1.129 | 1.120 | 1.085 | 1.076 | 1.084 | 1.109 | 1.041 | 1.090 | 1.059 | 1.145 | 1.076 |
| C9 | 1.138 | 1.191 | 1.179 | 1.098 | 1.158 | 1.183 | 1.179 | 1.140 | 1.170 | 1.138 | 1.129 | 1.163 | 1.089 | 1.136 | 1.093 | 1.219 | 1.147 |
| C10 | 1.143 | 1.198 | 1.188 | 1.102 | 1.156 | 1.172 | 1.186 | 1.139 | 1.141 | 1.164 | 1.147 | 1.175 | 1.093 | 1.171 | 1.109 | 1.226 | 1.132 |
| C11 | 1.109 | 1.164 | 1.177 | 1.082 | 1.130 | 1.155 | 1.156 | 1.116 | 1.114 | 1.108 | 1.152 | 1.160 | 1.083 | 1.142 | 1.097 | 1.174 | 1.130 |
| C12 | 1.053 | 1.108 | 1.099 | 1.015 | 1.067 | 1.091 | 1.087 | 1.054 | 1.053 | 1.053 | 1.052 | 1.122 | 1.019 | 1.073 | 1.029 | 1.122 | 1.059 |
| C13 | 1.089 | 1.150 | 1.163 | 1.055 | 1.131 | 1.121 | 1.133 | 1.102 | 1.091 | 1.086 | 1.088 | 1.139 | 1.094 | 1.118 | 1.072 | 1.160 | 1.106 |
| C14 | 1.141 | 1.207 | 1.194 | 1.115 | 1.162 | 1.179 | 1.202 | 1.164 | 1.152 | 1.143 | 1.165 | 1.182 | 1.095 | 1.197 | 1.104 | 1.232 | 1.176 |
| C15 | 1.099 | 1.152 | 1.117 | 1.040 | 1.095 | 1.116 | 1.118 | 1.084 | 1.072 | 1.071 | 1.090 | 1.119 | 1.052 | 1.084 | 1.089 | 1.151 | 1.088 |
| C16 | 1.075 | 1.128 | 1.101 | 1.021 | 1.086 | 1.097 | 1.114 | 1.069 | 1.064 | 1.053 | 1.064 | 1.099 | 1.039 | 1.079 | 1.027 | 1.165 | 1.064 |
| C17 | 1.156 | 1.207 | 1.198 | 1.108 | 1.183 | 1.189 | 1.208 | 1.161 | 1.160 | 1.144 | 1.177 | 1.197 | 1.114 | 1.181 | 1.126 | 1.225 | 1.191 |

**Table 10** Centrality and causality of perspectives and criteria

| | $d_i$ | $r_i$ | $d_i + r_i$ | $d_i - r_i$ | Cause or effect |
|---|---|---|---|---|---|
| P1 | 16.104 | 17.105 | 33.209 | − 1.000 | Effect |
| P2 | 16.315 | 17.920 | 34.236 | − 1.605 | Effect |
| P3 | 18.108 | 16.498 | 34.607 | 1.610 | Cause |
| P4 | 16.758 | 16.702 | 33.460 | 0.057 | Cause |
| P5 | 18.195 | 17.256 | 35.451 | 0.938 | Cause |
| C1 | 18.749 | 18.698 | 37.447 | 0.052 | Cause |
| C2 | 17.723 | 19.636 | 37.360 | − 1.913 | Effect |
| C3 | 18.395 | 19.403 | 37.799 | − 1.008 | Effect |
| C4 | 19.160 | 17.998 | 37.158 | 1.161 | Cause |
| C5 | 18.344 | 18.957 | 37.301 | − 0.613 | Effect |
| C6 | 19.123 | 19.257 | 38.379 | − 0.134 | Effect |
| C7 | 18.789 | 19.388 | 38.177 | − 0.599 | Effect |
| C8 | 18.609 | 18.760 | 37.369 | − 0.152 | Effect |
| C9 | 19.550 | 18.733 | 38.284 | 0.817 | Cause |
| C10 | 19.642 | 18.543 | 38.185 | 1.099 | Cause |
| C11 | 19.248 | 18.703 | 37.951 | 0.546 | Cause |
| C12 | 18.156 | 19.278 | 37.435 | − 1.122 | Effect |
| C13 | 18.899 | 18.025 | 36.925 | 0.874 | Cause |
| C14 | 19.809 | 18.946 | 38.756 | 0.863 | Cause |
| C15 | 18.637 | 18.176 | 36.813 | 0.460 | Cause |
| C16 | 18.346 | 19.868 | 38.215 | − 1.522 | Effect |
| C17 | 19.926 | 18.735 | 38.661 | 1.191 | Cause |

selection is an effect factor. Agi and Nishant (2017) also stressed that top management commitment is an influential factor on implementing GSCM. In line with them, this study also concluded that difficulty in eco-design (C6) belongs to the effect group, and the lack of top management support (C17) as well as difficulty in supplier selection (C10) are included in the cause group for managing green supply chains in China's SMEs. In accordance with Jayant and Azhar (2014), this study reveals that poor guidance from authorities (C14) is a key reason that blocks firms' GSCM road, and lack of environmental awareness and belief in environmental benefits is the noticeable failure factors of implementing GSCM. In Fig. 2, the results in this study show that lack of top management support (C17), difficulty in supplier selection (C10) and inadequate supplier commitment (C9) are the most important failure factors. This can also prove the main reasons for the GSCM failure in China's SMEs can be the lack of support and collaboration.

Though previous research found some companies have been increasingly aware of the environmental benefits and are willing to adopt GSCM (Govindan et al., 2014), this study shows that in China the lack of top management support (C17) is still a critical failure factor of GSCM. Due to the dictator bosses in these SMEs (Govindan et al., 2014; Wu et al., 2019a, 2019b, 2019c), implementing GSCM still requires them to radically alter their mindsets. The top managers must be willing to incorporate green practices into their supply chains to fairly take the place of the conventional profit-driven activities. Also, to avoid greenwashing, they must start to make outcome-based commitments related to GSCM, starting from more achievable outcomes and gradually avoid and offset more aspects of

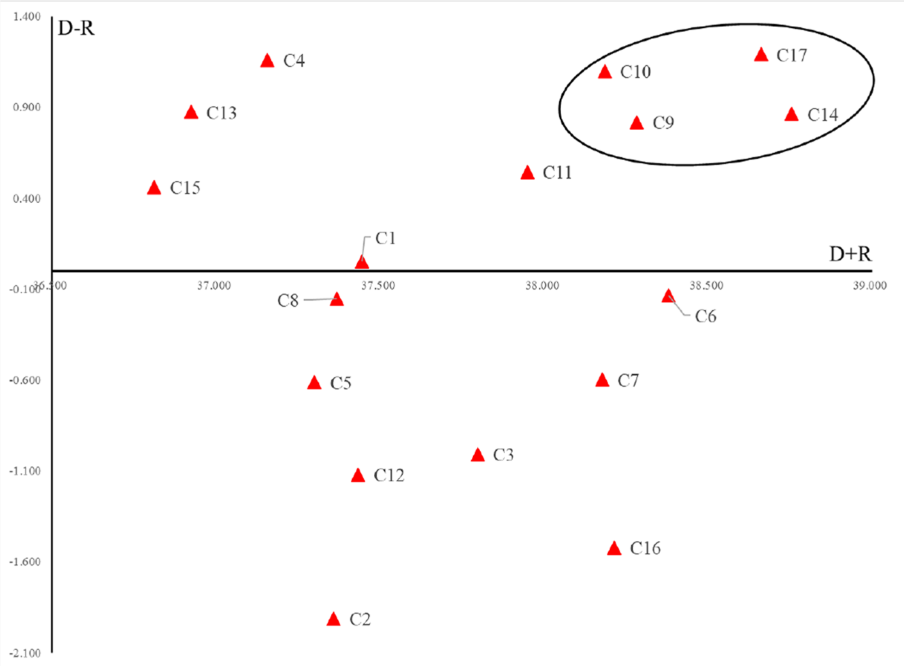



**Fig. 2** Cause–effect diagram of criteria

their environmental impacts along the supply chain. How top executives commit to making changes can affect the functions of the mid-level managers and the GSCM practitioners in the companies; top management support strengthens the cooperation among units and to deal with the difficulty and complexity of GSCM (Hu & Hsu, 2010; Mudgal et al., 2010).

Moreover, SMEs may fail to effectively launch GSCM due to the difficulty in supplier selection (C10). Supplier selection is a complex decision-making process which requires companies to carefully define proper criteria, effectively apply decision support tools and evaluate the performance of the suppliers (Tseng et al., 2019a). The evaluation and selection are made under diverse uncertainties and incomplete information. If companies fail to make sound decisions that avoid the omission of useful information, inaccuracies and biasedness, they may fail in developing their GSCM strategy (Sureeyatanapas et al., 2018). Furthermore, the suppliers' practices can be very difficult to monitor and measure, which may also cause failure in supplier selection. The collaboration with suppliers thus must to be fostered and maintained, and the communication channels also need to be properly established, aiming to bring convenience for companies exchanging information related to inter-organizational GSCM practices.

Inadequate supplier commitment (C9) is also a key factor that can lead to GSCM failure. The suppliers may be unwilling to exchange knowledge and information with other companies because of the risk of knowledge leakage and negative impacts on their corporate competitiveness. To solve this, companies should launch alliance regimes for knowledge acquisition and demonstrate their trustworthiness to the suppliers (Jiang et al., 2015). Besides knowledge and information, committed supplier is also required to allocate money, effort and time to improve the GSCM performance. Supplier commitment and cooperation enable companies to design and produce differentiated products and achieve a green and

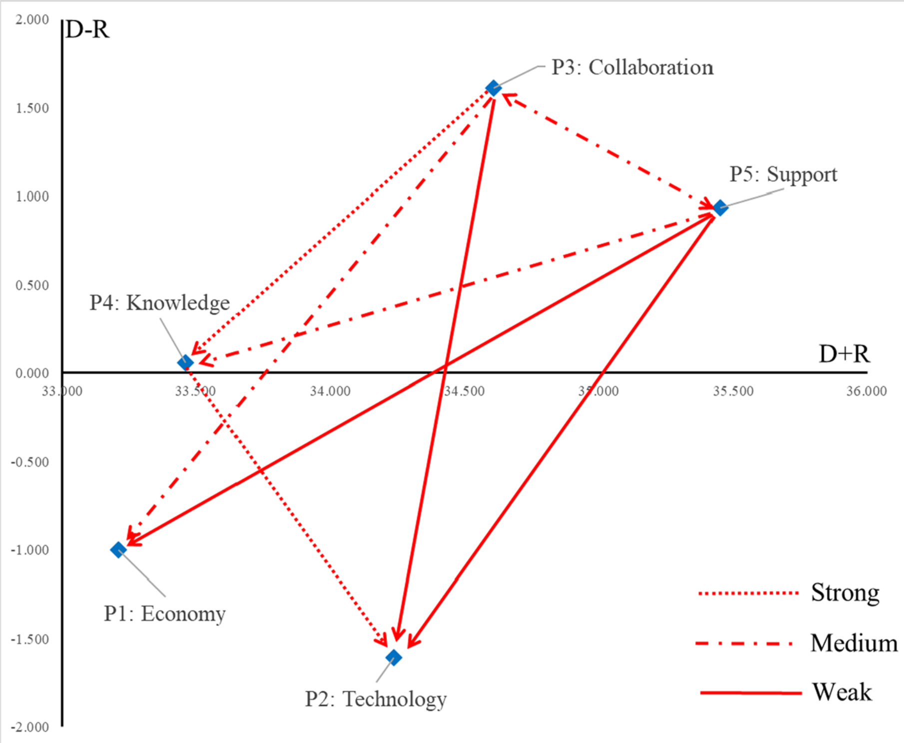
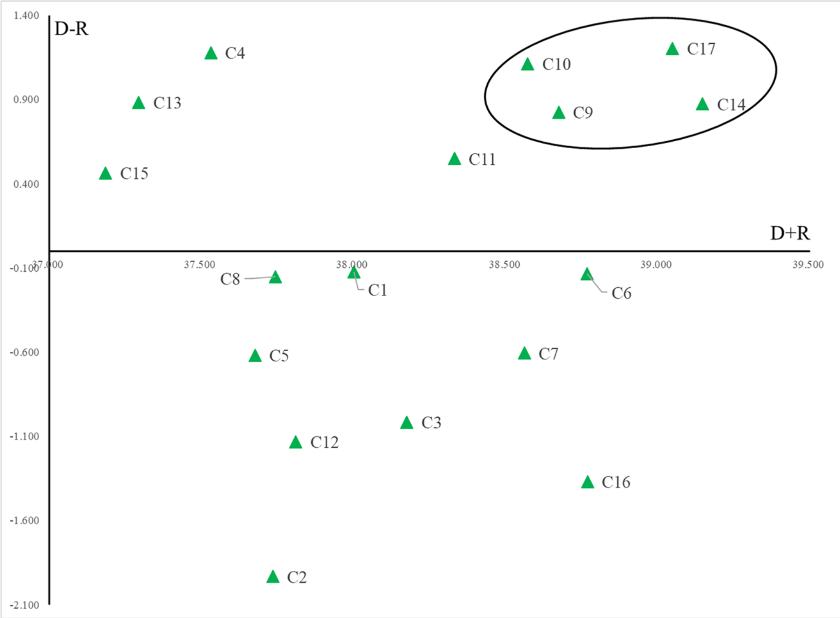



**Fig. 3** Cause–effect diagram of perspectives

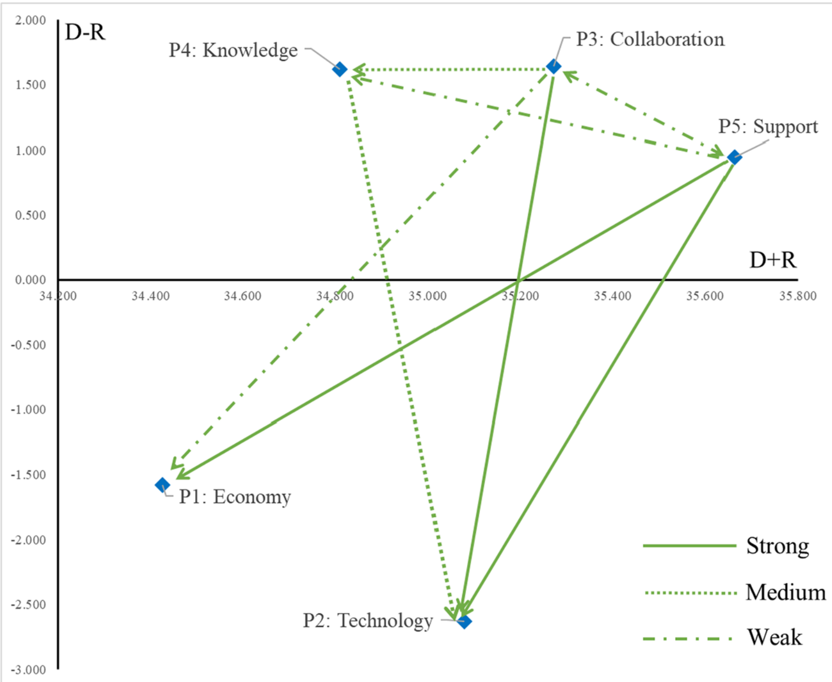
sustainable competitive advantage (Lees & Nuthall, 2015). In fact, many SMEs in China are willing to forge bonds with suppliers and other partners (Liu, 2012; Wu et al., 2019c). Thus, the current main challenge is to build trust between the companies and their suppliers, encourage the companies to incorporate the discussion of GSCM into the existing buyer–supplier relationship, and act GSCM practices as a system to guarantee long-run business development (Beske & Seurig, 2014; Lo, 2015).

## 7 Conclusions and limitations

In response to the international and national environmental targets, companies in China have been striving for balancing their economic and environmental performance adopting the strategy of GSCM. The SMEs play a key role in developing and achieving the economic prosperity of China and have been expected to enact GSCM to reduce their adverse environmental and social impacts (Tseng et al., 2019a). However, compared to the large companies, the SMEs are more likely to fail in managing green supply chain issues (Wooi & Zailani, 2010). In the previous literature, success factors of GSCM have been well discussed, while its failure factors for the China's SMEs are still lack of discussions. Therefore, this study developed a comprehensive framework with seventeen




**(a)** change of criteria




**(b)** change of perspective

**Fig. 4** Sensitivity result, [P4, C16] = [1, 1]

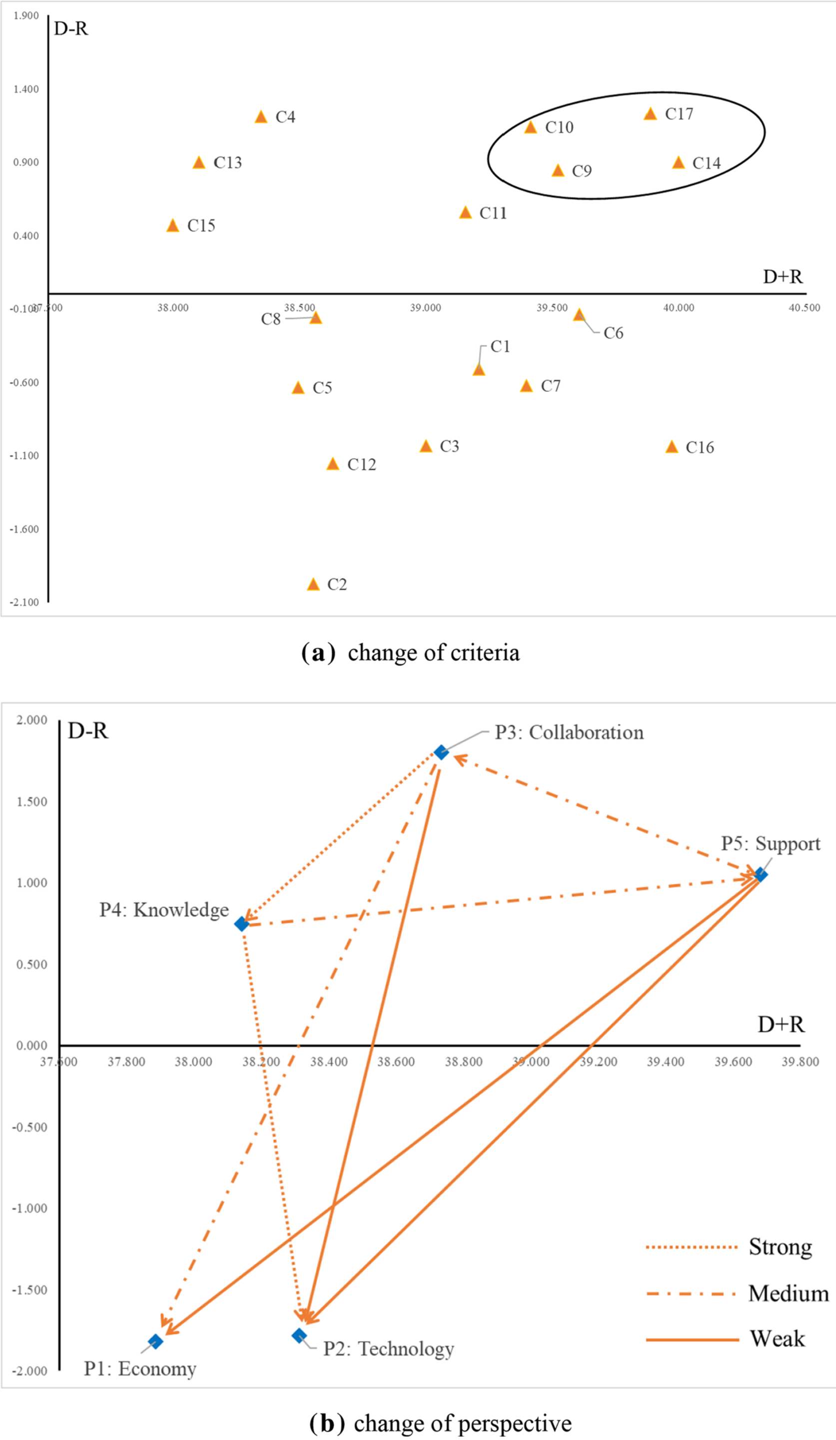



**Fig. 5** Sensitivity result, [P4, C16] = [5, 5]

failure factors under five perspectives for these companies to inform decision-makers about the failure factors in order to improve the opportunities of GSCM.

Moreover, this study also identifies the critical failure factors of GSCM in China's SMEs. A mixed decision technique combining the FSE and DEMATEL method is developed and utilized to collect experts' evaluation data and weigh the attributes while taking interrelationships into considerations with a cause–effect model. This method addresses the issue of subjective, imprecise and ambiguous judgement, converts the interrelationships among attributes into a hierarchical framework and visualize the interdependence of the factors in the intertwined problem. The results show that collaboration and support are the critical perspectives. These two also interrelated with each other and affect the other three perspectives, including knowledge, technology and economy. This points out that without adequate support from managers and authorities as well as supplier collaboration, it can be difficult to get enough economic resources, technology transfer and utilization, and enough business knowledge for developing GSCM. From the policy perspective, this research reveals that poor guidance from authorities is a critical failure factor. The local governments need to make clearer guidance for SMEs and the central government needs to greener their public procurement policies to foster green development. Practically, lack of top management support, difficulty in supplier selection and inadequate supplier commitment are the decisive managerial failure factors. Finally, a sensitivity analysis is carried out, revealing good robustness of the obtained results.

This study has the following three main contributions: (i) it studied the failure factors to inform decision-makers for promoting GSCM, in order to accelerate SMEs' sustainability transformation; (ii) it developed a hybrid FSE-DEMATEL method to address the interrelationship among the attributes with a cause–effect model; (iii) it identified the critical aspects and decisive failure factors that hamper China's SMEs from employing GSCM to support more efficient decision-making. However, this study still has some limitations. Firstly, though this study proposes a hierarchical structure which has been verified, future studies could further discuss other perspectives or factors to deeper understand the possible reasons and factors that can cause the collapse of GSCM. Secondly, this research only focuses on the China's SMEs and may not applicable to other countries; the critical failure factors may be different in other developing or developed countries. Therefore, future studies can investigate into the identification of the critical failure factors in other economies to prevent the failure of GSCM under different contexts. Last but not least, combining FSE with DEMATEL properly solved the factor analysis by providing a cause–effect model, but other instruments, such ISM and AHP, may also be worthwhile exploring for comparison with this study.

**Author contributions** All authors contributed to the study conception and design. Shuo Gao contributed to conceptualization, methodology and data collection; Ming Kim Lim contributed to methodology and writing—reviewing and editing; Renlu Qiao contributed to data collection and data analysis; Chensi Shen contributed to writing—reviewing and editing; Chentao Li contributed to writing—reviewing and editing; Li Xia contributed to methodology, data analysis and writing—original draft preparation; all authors read and approved the final manuscript.

**Funding** No funding was received to assist with the preparation of this manuscript.

**Availability of data and material** The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

**Code availability** The code applied in this study is available.

## Declarations

**Conflicts of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethical approval** Not applicable.

**Consent to participate** Not applicable.

**Consent to publication** Not applicable.

## References

Agi, A. N. M., & Nishant, R. (2017). Understanding influential factors on implementing green supply chain management practices: An interpretive structural modelling analysis. *Journal of Environmental Management, 188*, 351–363.
AlKhidir, T., & Zailani, S.(2009). Going green in supply chain towards environmental sustainability. Global *Journal of Environmental Research*, *3*(3),246–251.
Arimura, T. H., Darnall, N., & Katayama, H. (2011). Is ISO 14001 a gateway to more advanced voluntary action? The case of green supply chain management. *Journal of Environmental Economics and Management, 61*(2), 170–182.
Beske, P., & Seuring, S. (2014). Putting sustainability into supply chain management. *Supply Chain Management: An International Journal, 19*(3), 322–331.
Björklund, M., Martinsen, U., & Abrahamsson, M. (2012). Performance measurements in the greening of supply chains. *Supply Chain Management: An International Journal, 17*(1), 29–39.
Carter, C. R., & Dresner, M. (2001). Purchasing's role in environmental management: Cross-functional development of grounded theory. *Journal of Supply Chain Management, 37*(3), 12–27.
Chin, T. A., Tat, H. H., & Sulaiman, Z. (2015a). Green Supply Chain Management, Environmental Collaboration and Sustainability Performance. *Procedia CIRP, 26*, 695–699.
Cui, L., Chan, H. K., Zhou, Y., et al. (2019). Exploring critical factors of green business failure based on Grey-Decision Making Trial and Evaluation Laboratory (DEMATEL). *Journal of Business Research, 98*, 450–461.
Duber-Smith, D. (2005). *The Green Imperative*. Green Marketing Inc.
Emiliani, M. L. (2010). Historical lessons in purchasing and supply relationship management. *Journal of Management History, 16*(1), 116–136.
Gandhi, S., Mangla, S. K., Kumar, P., & Kumar, D. (2016). A combined approach using AHP and DEMATEL for evaluating success factors in implementation of green supply chain management in Indian manufacturing industries. *International Journal of Logistics Research and Applications, 19*(6), 537–561.
Gautam, H. C., Nagendra, S. S. (2018). Comparison of fuzzy synthetic evaluation techniques for evaluation of air quality: a case study. Recent Developments and the New Direction in Soft-Computing Foundations and Applications. Springer: Cham, pp.605–615.
Gao, S., Qiao, R., Lim, M. K., Li, C., Qu, Y., & Xia, L.(2021). Integrating corporate website information into qualitative assessment for benchmarking green supply chain management practices for the chemical industry. *Journal of Cleaner Production*, 127590
Govindan, K., Kaliyan, M., Kannan, D., & Haq, A. N. (2014). Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *International Journal of Production Economics, 147*, 555–568.
Hu, A. H., & Hsu, C. (2010). Critical factors for implementing green supply chain management practice: An empirical study of electrical and electronics industries in Taiwan. *Management Research Review, 33*(6), 586–608.
Jayant, A., & Azhar, M. (2014). Analysis of the Barriers for Implementing Green Supply Chain Management (GSCM) Practices: An Interpretive Structural Modeling (ISM) Approach. *Procedia Engineering, 97*, 2157–2166. https://doi.org/10.1016/j.proeng.2014.12.459

Jiang, X., Bao, Y., Xie, Y., & Gao, S. (2015). Partner trustworthiness, knowledge flow in strategic alliances, and firm competitiveness: A contingency perspective. *Journal of Business Research, 69*(2), 804–814.
Lees, N. J., & Nuthall, P. (2015). Case study analysis on supplier commitment to added value agri-food supply chains in New Zealand. *Agricultural and Food Economics, 3*, 4.
Liu, C.-L.E. (2012). An investigation of relationship learning in cross-border buyer–supplier relationships: The role of trust. *International Business Review, 21*(3), 311–327.
Lo, S. M. (2015). Impact of greening attitude and buyer power on supplier environmental management strategy. *International Journal of Environmental Science and Technology, 12*(10), 3145–3160.
Luthra, S., Garg, D., & Haleem, A. (2016). The impacts of critical success factors for implementing green supply chain management towards sustainability: An empirical investigation of Indian automobile industry. *Journal of Cleaner Production, 121*, 142–158.
Mathiyazhagan, K., Govindan, K., NoorulHaq, A., & Geng, Y. (2013). An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of Cleaner Production, 47*, 283–297.
Mudgal, R. K., Shankar, R., Talib, P., & Raj, T. (2010). Modeling the barriers of green supply chain practices: An Indian perspective. *International Journal of Logistics Systems and Management, 7*(1), 81–107.
Mumtaz, U., Ali, Y., Petrillo, A., et al. (2018). Identifying the critical factors of green supply chain management: Environmental benefits in Pakistan. *Science of the Total Environment, 640–641*, 144–152.
Perron, G. M. (2005). *Barriers to Environmental Performance Improvements in Canadian SMEs*. Dalhousie University.
Revell, A., & Rutherfoord, R. (2003). UK environmental policy and the small firm: Broadening the focus. *Business Strategy and the Environment, 12*(1), 26–35.
Saaty, T. L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill.
Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production, 11*(4), 397–409.
Shen, L. Y., & Tam, V. W. Y. (2002). Implementation of environmental management in the Hong Kong construction industry. *International Journal of Project Management, 20*(7), 535–543.
Spanellis, A., MacBryde, J., & Dörfler, V. (2020). A dynamic model of knowledge management in innovative technology companies: A case from the energy sector. *European Journal of Operational Research*. https://doi.org/10.1016/j.ejor.2020.11.003
Stern, N., & Xie, C. (2020). China's 14th Five-Year Plan in the context of COVID-19: Rescue, recovery and sustainable growth for China and the world. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
Sureeyatanapas, P., Sriwattananusart, K., Niyamosoth, T., Sessomboon, W., & Arunyanart, S. (2018). Supplier selection towards uncertain and unavailable information: An extension of TOPSIS method. *Operations Research Perspectives, 5*, 69–79.
Theyel, G. (2000). Management practice for environmental innovation and performance. *International Journal of Operations and Production Management, 20*(2), 249–266.
Tseng, M.-L., Islam, M. S., Karia, N., Fauzi, F. A., & Afrin, S. (2019a). A literature review on green supply chain management: Trends and future challenges. *Resources, Conservation and Recycling, 141*, 145–162.
Tseng, M.-L., Lim, M. K., & Wu, K.-J. (2018). Corporate sustainability performance improvement using an interrelationship hierarchical model approach. *Business Strategy and the Environment, 27*(8), 1334–1346.
Tseng, M., Wu, K., Ma, L., Kuo, T. C., & Sai, F. (2019b). A hierarchical framework for assessing corporate sustainability performance using a hybrid fuzzy synthetic method-DEMATEL. *Technological Forecasting and Social Change, 144*, 524–533.
Walker, H., Di Sisto, L., & McBain, D. (2008). Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of Purchasing and Supply Management, 14*(1), 69–85.
Wang, L., & Wu, C. (2017). Business failure prediction based on two-stage selective ensemble with manifold learning algorithm and kernel-based fuzzy self-organizing map. *Knowledge-Based Systems, 121*, 99–110.
Wijethilake, C. (2017). Proactive sustainability strategy and corporate sus- tainability performance: The mediating effect of sustainability control systems. *Journal of Environmental Management, 196*, 569–582.
Wooi, G. C., & Zailani, S. (2010). Green Supply Chain Initiatives: Investigation on the Barriers in the Context of SMEs in Malaysia. *International Business Management, 4*(1), 20–27.

Wu, K.-J., Chen, Q., Qi, Y., Jiang, X., Gao, S., & Tseng, M.-L. (2019a). Sustainable Development Performance for Small and Medium Enterprises Using a Fuzzy Synthetic Method-DEMATEL. *Sustainability, 11*(15), 4119.

Wu, K.-J., Gao, S., Xia, L., Tseng, M.-L., Chiu, A. S., & Zhang, Z. (2019c). Enhancing corporate knowledge management and sustainable development: An inter-dependent hierarchical structure under linguistic preferences. *Resources, Conservation and Recycling, 146*, 560–579.

Wu, Y., Jia, W., Li, W., et al. (2019b). Risk assessment of electric vehicle supply chain based on fuzzy synthetic evaluation. *Energy, 182*, 397–411.

Yazdi, M., Khan, F., Abbassi, R., & Rusli, R. (2020). Improved DEMATEL methodology for effective safety management decision-making. *Safety Science, 127*, 104705.

Zhang, B., Bi, J., & Liu, B. (2009). Drivers and barriers to engage enterprises in environmental management initiatives in Suzhou Industrial Park, China. *Frontiers of Environmental Science & Engineering in China, 3*(2), 210–220.

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management, 22*(3), 265–289.

Zhu, Q., Sarkis, J., & Lai, K. H. (2007). Green supply chain management: Pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production, 15*(11–12), 1041–1052.



## Authors and Affiliations

**Shuo Gao[1] · Ming Kim Lim[2] · Renlu Qiao[3] · Chensi Shen[4] · Chentao Li[5] · Li Xia[6]**

Shuo Gao
shuo.gao@foxmail.com

Ming Kim Lim
ming.lim@cqu.edu.cn

Renlu Qiao
renluqiao@gmail.com

Chensi Shen
chensi.shen.tju@gmail.com

Chentao Li
lichentao128@gmail.com

[1] Interdisciplinary Centre for Conservation Science, University of Oxford, Oxford, UK

[2] Department of Industrial Engineering, College of Mechanical Engineering, Chongqing University, Chongqing, China

[3] School of Architecture, Tianjin University, Tianjin, China

[4] Department of Geography and Environment, London School of Economics and Political Science, London, UK

[5] Department of Sociology, London School of Economics and Political Science, London, UK

[6] School of Management, University of Science and Technology of China, Hefei, China