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ORIGINAL RESEARCH

Leagile supplier selection in Chinese textile industries: a DEMATEL approach

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Abstract

Industries across the globe are under growing pressure to rethink and redesign their supply chain operations to maintain their competitive advantage. The supplier selection process in supply chain management holds a pivotal position in its exploration of new strategies to stay competitive in global markets. This study considers supplier selection with two different strategic perspectives, including lean and agile. Selecting suppliers based on their leagile practices helps the focal industries to make their supply chain operations healthier, especially if the focal industry is a major supplier of multinational companies. China is considered as a case context in this study with the application of textile sectors since this country occupies the top position with regard to exports. The common criteria involved in leagile supplier selection were collected from existing literature resources and were fine-tuned with insights from field experts. Further, the case industrial managers also assisted with the evaluation of the influential criteria for the leagile supplier selection process. Based on the replies and the assistance of a decision-making trial and evaluation laboratory tool, the most influential criterion and interdependencies among other criteria were identified. This study helps industrial managers to evaluate their suppliers based on the resultant influential criterion and, further, it strengthens the global supply chains with agility and robustness.

Keywords Leagile · Supplier selection · China · Textile sector · DEMATEL

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1 Introduction

In today's competitive environment, supply chain management plays a vital role in improving the performance of any organization. However, supply chains are not a new focus to academicians. Since the late 1990s, supply chain concepts have been a popular topic, especially those concepts that enable subsequential technological and social changes (Asree et al. 2018). After the occurrence of the globalization movement, customers seek products of high quality and low cost. When those customers are not restricted due to geographical limits, several opportunities exist to demand that supply chains perform better. For the time being, the major threat of supply chain management is balancing supply and demand; many well-known companies still struggle with this challenge. To manage this problem, several strategies are commonly put into practice, and even more practices are being explored by researchers worldwide to balance supply and demand in fast-moving supply chains. One key strategy to maintain the supply demand is to select the best supplier who offers a high reliability of product quality and long term stability in the business. Suppliers are the backbone of any well-known organization, and inefficient suppliers can produce great damage to a focal company's business, even more damage than that of the company's own inefficiencies. Nearly 65–75% of capital cost is invested in the procurement of raw materials, and that link depends on efficient supplier selection. For instance, a major fire occurred in a Bangladesh textile industry due to their handling inefficiencies, and that accident caused a major disruption in EU textile supply chain. In fact, the whole supply chain suffered from an overall failure for quite some time. If the EU companies had properly trained the supplier, or if the proper supplier had been selected, they may have been able to safeguard themselves during such unlikely events. Due to these important considerations, the supplier selection process becomes tedious and more available of recent technologies incorporation in supplier selection make the industries confused in terms of which criteria they have to select the suppliers. With this concern, this study explores the common criteria of supplier selection based on their leagile practices; we further evaluate the most influential criterion among common criteria. Leagile is one of the recent strategies to make industries more efficient and capable of staying competitive in the global marketplace. These strategies were developed with one objective: to stay in the competitive market through providing final consumers with the right product, at the right time, at the right price (Iyengar and Bharathi 2018; Chowdary and Fullerton 2019).

'Leagile' integrates the concepts of 'Lean' and 'agile' in the same phenomenon; both concepts serve different requirements of companies to help them in competitive markets (Kumar and Kumar 2017; Ambe 2017). Often, practitioners confuse these two terms. Several definitions are available in the literature, but the most acclaimed defintitions were given by Naylor et al. (1999) and Mason-Jones et al. (2000a, b) as follows. 'Leanness' is defined as "developing a value stream to eliminate all waste, including time and to ensure a level schedule." On the other hand, 'agile' is defined as "Using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place." The combined definition of 'Leagile' may be formulated as "the combination of the lean and agile paradigms within a total supply chain strategy by positioning the decoupling point so as to best suit the need for responding to a volatile demand downstream, yet providing level scheduling upstream from the marketplace." While these concepts are different in nature, with the effectiveness of certain business models, the leagile can be adapted successfully in global supply chains including supplier selection (Mason-Jones 1999; Agarwal et al. 2006).

A decade ago, supplier selection and supply chain activities generally focused only on the Lean supply chain and Lean supplier selection, despite that the sole implementation of Lean in a supply chain does not produce an advantage of reacting to market change. According to Elkins et al. (2004) and Iyengar and Bharathi (2018), in order to deal with uncertainty and volatile vulnerability in the current business market, certain strategies are needed to accompany the concepts of leanness. Agility is capable of dealing with uncertainties in demand when the number of products is high. Thus, more studies (Manzouri et al. 2015; Alkahtani et al. 2019; Lotfi 2019) began to examine agile systems in supply chain management. As an extension, researchers started to integrate Lean and agile methods to reap the benefits of both: eliminating waste and responding quickly. This combined package serves more benefit to the end customers and to the multiple stakeholders involved in the supply chain.

Supplier selection based on the leagile perspective provides an edge to focal companies by reducing raw material cost, increasing quality, offering better delivery and customer satisfaction, and improving reactions to market changes. Hence, it is worthwhile topic to consider supplier selection based on their leagile practices. Several studies already made an attempt to explore the Lean and agile supplier selection processes; however, those studies present limited criteria and do not integrate the two concepts equally. In addition, this study was conducted in a Chinese context, who are the suppliers of several big companies in US and EU (especially in the textile sector). With these considerations, this study explores the supplier selection process in the Chinese textile industries with their leagile abilities. The intention of this study is not to select the best supplier; instead, it provides a framework where ‘**n**’ number of suppliers can fit in. Based on the proposed framework, the industry/company can select its suppliers with regard to their leagile practices. This framework highlights the most influential criterion and interdependencies among other criteria, which could help case industrial managers to select suppliers based on the most influential leagile criteria. For solving the objective, a multi-criteria decision making (MCDM) tool has been adopted: namely, decision making trial and evaluating laboratory (DEMATEL). The comparison replies among criteria were collected from case industrial managers and the same were gathered as inputs to DEMATEL.

The remaining sections are as follows: Sect. 2 deals with the existing literatures available with the core concern of this study and detailed with five subsections. The solution methodology, which is given as Sect. 3, deals with the tools involved in this study to evaluate the supplier selection criteria. Moreover, the importance of the method adopted and the steps involved has been included. Section 4 describes the case and any problems regarding supplier selection, and this section provides the proposed framework for analyzing the leagile supplier selection criteria. The proposed model is applied and explained in Sect. 5. Section 6 presents the discussion and managerial implications of the obtained results. Finally, this study concludes in Sect. 7 with a summary, recognized limitations, and a proposed future scope of the concerned research.

2 Literature review

The aim of this section is to explore current state of the art resources pertaining to the concerned topic, leagile supplier selection. In addition, we seek to bridge the gap between the virtual applications and literature perspectives in the focal field. This section is categorized into five subsections: namely, leagile supply chain, Lean supplier selection, agile supplier selection, DEMATEL in supplier selection, and the research gap and concerned objectives. Each subsection serves its purpose to validate the novelty of the concern research.

2.1 Leagile supply chain

Most studies present the concepts of leagile supply chains, including metrices, strategies, drivers, barriers and so on. For instance, Rahiminezhad Galankashi and Helmi (2016) studied the leagile supply chain strategies based on their drivers. This study ranked the leagile supply chain strategies based on their proposed framework with the assistance of AHP. Goldsby et al. (2006) proposed leagile strategies for supply chains through the simulation analysis with the case context of a first tier supplier who supplies companies manufacturing air conditioners. Mason-Jones et al. (2000a, b) explains the integration of lean and agile with the decoupling point in total supply chains. In addition, performance metrics are presented to evaluate the leagility on the company's supply chain. Mason-Jones et al. (2000a) introduced a new paradigm, the leagile paradigm, with which this study correlates the demand matching in a supply chain within the marketplace through decoupling lean and agile as leagile.

A few studies discuss the metrics of leagile supply chains. Ramana et al. (2013) evaluates the metrics of leagile supply chains with the assistance of logarithmic least square method under a fuzzy environment. This study considers the small and medium scale enterprise as a case context to explore the metrics of leagile supply chains. Agarwal et al. (2006) proposes an ANP approach to evaluate the metrics of leagile in supply chain environments; further, this study explores the relationship between the leanness and agility of the supply chain operations.

Some studies seek to prove the significance of adapting leagile strategies in supply chains. For instance, Amir (2011) explores the importance of connecting lean and agile in supply chain management. With the assistance of a literature review, this study demonstrates the significance of leagile through decoupling point in supply chain applications. Zhang et al. (2012) compares two different supply chains, including traditional supply chains and leagile supply chains, through proposed dynamic simulation model. Finally, the study concludes that leagile supply chains are more flexible with dynamic markets than those of conventional supply chains. Haq and Boddu (2017) investigate enablers of leagile supply chain management, with the assistance of quality function development under uncertainty using a fuzzy approach. Further, AHP and TOPSIS have been adapted to enhance the implementation of leagility in supply chain management.

A considerable number of studies focus on the performance measurement and reliability of leagile supply chains, including Soni and Kodali (2009), who developed a multi attribute decision making model to evaluate the performance of implementing leagile supply chain management. Soni and Kodali (2012) evaluated the leagile reliability and validity in supply chains through proposed standard constructs. Maharaja et al. (2018) proposed a measurement system to determine the leagile performance of a company in their supply chains. This study proposed a performance index, which was further illustrated with a real life case study.

Some studies involve a review of Lean and green supply chains with various concepts. For instance, Iyengar and Bharathi (2018) review the literature published over the time period 1990–2017 with the concern of lean, agile and leagile supply chains in an automobile industry; they clearly state that there is only one study that exists in the leagile paradigm. In addition, this study seeks to investigate more leagile concepts because several opportunities exist. Cicculo et al. (2018) made a literature review on lean and agile supply chain paradigms combining the aspects of environmental and social sustainability. However, this study does not concentrate heavily on lean and agile interlinks; instead, their major focus emphasizes agile-sustainability and lean-sustainability methods.

Due to the different dimensions of considering leagile in supply chains, certain studies particularly focused on supplier selection and partnership processes. Qrunfleh and Tarafdar (2013) explored the relationship between the leagile supply chain strategies and their responsiveness on overall supply chain with the concern of strategic supplier partnership and postponement. This survey data includes supply chain managers from US-based manufacturing firms with the total number of 205. Further, the data were processed with structural equation modeling using AMOS software. El-Mokedam (2017) identified the impact of interrelationships between the supplier selection criteria with business strategies. A hypothesis was made and empirically tested to confirm that leagile based supplier selection strategies have a high impact on a business firm's overall competitive performance.

2.2 Lean supplier selection

Compared to agile supplier selection, few studies pursue lean supplier selection; more often, lean supplier selection is combined with green supplier selection. Very few studies focus only on lean supplier selection. Rahiminezhad Galankashi and Helmi (2016) studied the supplier selection process with lean concerns with the assistance of data envelopment analysis (DEA) approach. This study includes four pillars of lean systems: namely, cost, quality, lead time, and service level. Over 16 sub-selection criteria were considered for selecting suppliers based on their leanness. Initially, the weightage for each dimension was assessed and further extended the weightage process to their respective criteria. The whole study was conducted on an Iran semiconductor industry based on the replies of decision makers under nominal group technique. Birgün Barla (2003) studied the supplier selection with lean concepts by proposing the lean criteria of reliability, capability, quality organization, geographical condition, financial condition, service, and price. Yu et al. (2012) explored the supplier selection problem under uncertainty environment through a fuzzy approach. This study has considered major lean criteria for supplier selection including cost, delivery, and quality. Two different methodologies were combined, AHP and fuzzy multi objective programming. Chun Wu (2003) integrated two concepts including lean manufacturing and lean suppliers. This study highlights the importance of concerning lean suppliers and their impact on the implementation of lean manufacturing in the industries. The difference between the lean suppliers and non-lean suppliers has been explored with the context of lean manufacturing. The study concludes that there is an competitive edge on considering lean suppliers over non-lean suppliers to promote the implementation of lean manufacturing.

As discussed earlier, more studies combined lean with green in the supplier selection process. Torğul and Paksoy (2019) proposed an approach to select the supplier based on their green and lean performances under a fuzzy environment. TOPSIS has been applied to rank the suppliers, while AHP is used to evaluate the weights of each criteria in addition to a multi objective linear programming model. Çalik et al. (2019) selected suppliers based on the green and lean practices for a Turkey-based electronics board manufacturing industry using proposed multi objective linear programming model. This study considered 12 lean and green (combined) criteria under three dimensions, namely economy, environment, and social.

2.3 Agile supplier selection

Several studies have reported on agile supply chains, but in terms of agile supplier selection, limited studies have been identified.

Beikkhakhian et al. (2015) rank suppliers based on their agile practices using the proposed interpretive structural modeling (ISM) model combined with fuzzy TOPSIS-AHP methods. In this study, manufacturing industry has been considered as case industry with a total of six suppliers as alternatives with considered agile criteria. Rahiminezhad Galankashi and Helmi (2016) studied the supplier selection process with agile criteria under a fuzzy environment in order to deal with uncertainties. AHP has been used to evaluate the suppliers based on their agile activities; however, this study considered 12 criteria for agile supplier selection under four themes, including virtual enterprise, market sensitivity, process integration, and network based supply. Nominal group technique was adapted to extract the input for evaluation, and semiconductor manufacturing industries were used as a case context. Luo et al. (2009) studied the agile supplier selection problem with the concern of addressing information processing problems. This study adopted an artificial neural network to evaluate the suppliers based on both quantitative and qualitative data. The proposed methodology has been illustrated with the electrical appliances and equipment manufacturing industry in Chinese context. Hasan et al. (2008) utilized the ANP and data envelopment analysis to evaluate the suppliers based on their agile manufacturing environment. The proposed model has been illustrated with an Indian manufacturing company under four key factors: ability to modify product/process, schedule reaction, human factors, and agility enhancing factors. However, each of the four major factors considered includes three subfactors to evaluate the supplier among nine alternatives. Wu and Barnes (2009) proposed a model framework for supplier selection under agile environment; however, this framework includes the feedback from the focal industry so that it can help to improve the process continuously. Wu et al. (2009) proposed a partner selection framework with the concern of agile supply chains. This study integrates the ANP and mixed integer multi objective programming model in two phases. Wu and Barnes (2014) proposed a partner selection framework in a fuzzy environment concerning the elements of agile supply chains. Based on qualitative and quantitative data given by 84 Chinese electrical components and equipment industries, the partner selection was completed. An artificial neural network was applied to select the partner based on the proposed agile criteria.

2.4 DEMATEL in supplier selection

DEMATEL is one of the solid MCDM methods which has been applied in several functionalities. However, because this study focuses on the supplier selection processes, the recent applications of DEMATEL in supplier selection are discussed below.

DEMATEL has a wide range of applications with different concerns. For example, the approach (fuzzy, grey) may be mixed with other MCDM tools (DEMATEL-ANP, DEMATEL-TOPSIS), strategy (lean, green, agile), and so on. Hence, each of the different themes is summarized with relevant recent studies. Parkouhi et al. (2019) studied the supplier selection process under uncertainty environment using grey approach. This study adapted the DEMATEL for selecting the suppliers based on two themes of resilience enhancer and resilience reducer. Some studies combined the DEMATEL with other MCDM techniques. Liu et al. (2018) integrated the DEMATEL, analytical network process (ANP), and game theory to evaluate the supplier. In addition to this integration, several theories and methods are included such as Dempster-Shafer Theory, entropy method, and so on. This study considered conventional supplier selection process including dimensions like business improvement, extent of fitness, quality, services, and risks. Abdel-Basset et al. (2018) integrated the DEMATEL with neutrosophic set theory for supplier selection process. This study selected the best supplier for the distribution company considering seven major criteria for supplier selection, which includes cost, time delivery, quality, innovation, reputation, response to customers, and location. Kumar et al. (2018) proposed a decision making model with capital procurement for the construction sector using the integrated solution methodologies including Delphi, analytical hierarchy process (AHP), and DEMATEL. This study considered a total of eight criteria for selecting suppliers for their construction industry, which includes supplier profile, cost of ownership, service support, delivery adherence and history, manufacturing flexibility and maintainability, customer feedback, conformity with requirements, and usage of next generation.

Very few studies reported with the application of agile supplier selection with DEMATEL. Alimardani et al. (2014) made a study on supplier selection based on supplier's agile ability. This study combined DEMATEL with ANP and TOPSIS for processing both quantitative and qualitative factors. Alimardani et al. (2013) studied the supplier selection in agile environment with the combination of methodologies including DEMATEL, SWARA, and VIKOR. Few studies combined the agile supply chain and manufacturing with the evaluation done by the DEMATEL. Bathrinath et al. (2019) studied the agile criteria involved in Indian metal fabrication industry with the assistance of DEMATEL. On the other hand, there is no previous study (best of our knowledge) that has explored the lean supplier selection with DEMATEL.

2.5 Research gap and concern objectives

The previous subsections discussed various categories of the focused research, and from the understanding of this review, certain conclusion can be made. (i) There is no equal number of studies on lean supplier selection with agile supplier selection. (ii) Very limited studies have considered the leagile paradigm in supply chain, especially with supplier selection. (iii) No previous study combines the leagile perspective in supplier selection, although some studies consider either one of these concepts, but miss the decoupling point in procurement process. (iv) There is no evidence on Chinese context regarding with leagile supplier selection, and this study focused on textile industry where no previous attempts were made. Despite that there is not enough evidence to support the decision making process on supplier evaluation with leagile factors, this study concerns itself with the following objectives.

- To explore the importance of decoupling lean and agile as 'leagile'.
- To understand the effectiveness of leagile in supplier selection.
- To collect the common criteria for selecting the suppliers based on leagile.
- To identify the influential criterion and interdependencies on other common criteria over another.
- To provide implications and recommendations regarding the effective supplier selection process with concern of leagile.

3 Solution methodology

Supplier selection is indeed a tedious process due to the many factors involved in the decision making process. This study connects two concepts as leagile, so the process becomes more complex than with the conventional supplier selection problem. From the literature, it can be easily evident that multi criteria decision making trial and evaluation laboratory (MCDM) tools are significantly used for selecting suppliers regardless of their application sector. However, among MCDM, there are several tools that have been investigated and applied for in the supplier selection process. These tools can be broadly classified as those for identifying the influence among criteria and those for evaluating the alternatives. The main aim of this study is to understand the influence among leagile criteria for supplier selection; hence, this study emphasizes the tools that analyze the interrelationships and influences. A most acclaimed tool for analyzing the influence among the criteria was adapted in this study, DEMATEL. This tool is favored over other available tools due to its nature of considering the cause effect relationship among considered criteria (Kumar and Dash 2016; Kumar et al. 2018). Based on these influences and interrelationships, interdependencies among the considered criteria can be drawn which could be used as an additional means to solve the problem. DEMATEL uses the structural modeling approach to explore the cause criteria and effect criteria through the representation of an influential diagraph. Fontela and Gabus at Science and Human Affairs Program of the Battelle Memorial Institute of Geneva (Abdollahi et al. 2015) developed DEMATEL in 1972. Since the inception due to DEMATEL's advantages, many literatures have started to implement DEMATEL in their studies with different fields of applications including supply chain, education, engineering, construction, business management, hospitality, pharma, oil and gas, sustainability, and many more. With this evidence of success, this study selected DEMATEL to analyze the leagile criteria for supplier selection.

The step by step methodology for DANP mentioned below is adapted from Hsu et al. (2012).

Step 1: Calculate the initial relationship matrix 'A'

The first step of DANP is to calculate the initial relationship matrix 'A' based on the replies from the industrial and field experts based on the scale ranging from 0 to 4 where 0 is 'no influence,' 1 is 'very low influence,' 2 is 'low influence,' 3 is 'high influence,' and 4 is 'very high influence.'

$$\tilde{\boldsymbol{A}} = \begin{bmatrix} 1 & \mathrm{a12} & \mathrm{a13} & \ldots. & \mathrm{a1(n-1)} & \mathrm{a1n} \\ \mathrm{a21} & 1 & \mathrm{a23} & \ldots. & \mathrm{a2(n-1)} & \mathrm{a2n} \\ \ldots. & \ldots. & \ldots. & \ldots. & \ldots. & \ldots. \\ \ldots. & \ldots. & \ldots. & \ldots. & \ldots. & \ldots. \\ \mathrm{a(n-1)1} & \mathrm{a(n-1)2} & \mathrm{a(n-2)3} & \ldots. & 1 & \mathrm{a(n-1)n} \\ \mathrm{an1} & \mathrm{an2} & \mathrm{an3} & \ldots. & \mathrm{an(n-1)} & 1 \end{bmatrix} \quad (1)$$

Step 2: Calculate the normalized direct-relationship matrix 'X'

The initial matrix which is obtained from step 1 is normalized through the equations

$$K = \frac{1}{max_{1 \le i \le n}} \sum_{j=1}^{n} a_{ij} \quad (2)$$

$$X = K \times A \tag{3}$$

Step 3: Calculate the total influence matrix 'T'

The next step is identifying the total influence matrix. It is obtained with the aid of 'X' which is calculated in the previous step through Eq. 4 where 'I' implies the identity matrix.

$$\boldsymbol{T} = \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^h = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}, \quad \text{when} \quad \lim_{h \to \infty} \boldsymbol{X}^h = [0]_{n \times n} \tag{4}$$

Explanation,

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^h \\ &= \boldsymbol{X}\left(\boldsymbol{I} + \boldsymbol{X} + \boldsymbol{X}^2 + \cdots + \boldsymbol{X}^{h-1}\right)(\boldsymbol{I} - \boldsymbol{X})(\boldsymbol{I} - \boldsymbol{X})^{-1} \\ &= \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X}^h)(\boldsymbol{I} - \boldsymbol{X})^{-1}\end{aligned}$$

then,

$$\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}, \quad \text{when} \quad h \to \infty.$$

Step 4: Calculate the sum of rows and columns

'r' and 's' denote the sum of rows and columns. It is obtained through Eqs. (5) and (6).

$$\boldsymbol{r} = [r_i]_{n \times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1}, \quad \boldsymbol{s} = [s_j]_{n \times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1 \times n} \tag{5}$$

$$\boldsymbol{T} = [t_{ij}], \quad i, j = 1, 2, \ldots, n, \tag{6}$$

Step 5: Set up causal influence diagram

If r_i is the sum of the ith row in matrix $\boldsymbol{T}$, then r_i shows the sum of influence of factor i on the other factors. If s_j is the column sum of the jth column of matrix $\boldsymbol{T}$, then s_j shows the sum of influence of factor j on the other factors. With the assistance of 'r' and 's' we need to set up the causal influence diagram.

4 Case description and framework of the study

Most developed nations have suppliers in developing nations, including China and India. China is reknown as a global supplier, and according to statistical data, China is the world's largest exporter of goods since 2009. Other than electronics goods, China is well known for supplying cotton ($15 billion) and textile ($140 billion) products to worldwide industries. The case industry is one of the major companies in the textile field; it is situated in Jiangsu Province, China. They are more specialized in polyester fabrics including garment fabric, home textile, technical textiles, and so on. In addition, they offer textile solutions such as dyeing, coating, printing, bonding, weaving, and much more. They are striving hard with many new strategies to be competitive in the business markets. Due to their brand reputation, they have a substantial number of clients in developed nations. Through recent years, after the fast forward business model invention, high political instability forced the global companies to select their supplier based on leagile criteria. This case industry also has demand from global companies to implement leagile practices in their organization including supply chain operations. With these pressures, the case industry has already begun to implement leagile business models in their operations, and it is expected they will extend the model to the supplier selection process. Meanwhile, our research team sent proposals to a number of companies regarding the theme of the research, and we were invited from this case company due to the above stated reasons. After the approval from the case industry, a framework was proposed with the concern of leagile criteria for supplier selection, which is shown in Fig. 1. To achieve the research objective this proposed framework was applied within the case industry.

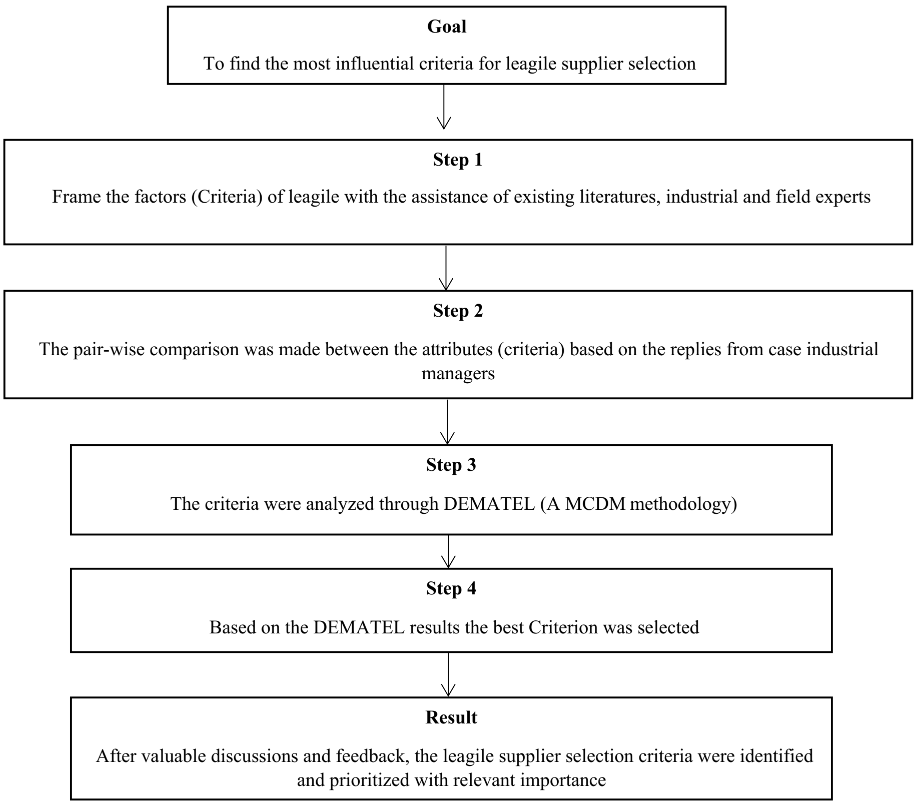

Fig. 1 Proposed framework for identifying influential leagile suppler selection criteria

5 Application of proposed framework: an illustration

This section focuses on the application of proposed framework in the case industry. The framework consists of three phases: frame the leagile factors for supplier selection, questionnaire development and pairwise comparison, and analysis of leagile criteria using DEMATEL. Each of the phases is detailed below.

Step 1: Frame the leagile factors for supplier selection

In this initial step, the leagile factors for supplier selection are framed. It is done through the combined assistance of existing literature and advice from field experts. From this assistance, common leagile criteria for supplier selection are identified and presented in Table 1. For literature review, the standardized review procedure is incorporated, and for assessing the advice from field experts, a 1-day workshop has been conducted.

Step 2: Questionnaire development and pair-wise comparison

The next step is to develop the questionnaire based on the collected common leagile criteria; further, the same has been circulated to the industrial case decision makers for their replies. The questionnaire involved with the criteria were assessed with a 0–4 scale where 0 represents 'no influence' to 4 represents 'very high influence.' Based on their replies, pair-wise comparisons were made between the collected common leagile criteria.

Step 3: Analysis of leagile criteria using DANP

To analyze the influential criteria, DEMATEL was applied. As discussed in the earlier section, analyzing the criteria with DEMATEL is done through some steps which are as follows:

(a) Calculate the initial relationship matrix 'A'
Based on the replies from the industrial managers and experts, the initial relationship matrix for leagile criteria were formed as a form of Eq. (1) which shown in Table 2.
(b) Calculate the normalized direct-relationship matrix 'X'
The initial relationship matrix is normalized through Eqs. (2) and (3) to form the normalized direct-relationship matrix 'X' which is shown in Table 3.
(c) Calculate the total influence matrix 'T'
The normalized direct relationship matrix is applied through Eq. (4) to get the total influence matrix 'T' which is shown in Table 4.
(d) Calculate the sum of rows and columns
From the total influence matrix, we need to calculate the sum of rows and sum of columns; the sum of rows is mentioned as 'r_i' and the sum of columns is denoted as 's_i' with the assistance of the Eqs. (5) and (6) for criteria which is shown in Table 5.
(e) Set up causal influence diagram
The causal influence diagram is made up of two axes, one is formed by $r_i + s_i$ and other is $r_i - s_i$ which acts as x and y axis, respectively. The factor at the top of the graph is the most influencing factor among the others, and the factor at the bottom of the graph is the least influencing factor. The causal influence diagram for leagile criteria is shown in Fig. 2.

Table 1 Collection of common leagile criteria for supplier selection

S. no.	Criteria	Description
1	Cost and pricing (**C1**)	The supplier cost effectiveness and dynamic pricing on the product based on the supply and demand
2	Quality (**C2**)	The total quality management of operations, product and processes involved in the supplier's company
3	Sourcing (**C3**)	The sourcing activities of suppliers with the concern of leagile in their sourcing strategies
4	Transportation (**C4**)	The measure of flexible transportation and structured collaboration
5	Service level and customer satisfaction (**C5**)	The supplier service level with shortened lead-time and customer satisfaction under uncertainty situations
6	Information (**C6**)	Facilities having electronic data exchange for both and external, IoT integration for autonomous control and operative outbound logistics
7	Inventory (**C7**)	The concern of vendor flexibility system, leagile inventory system, and inventory flexibility
8	Facility layout and location (**C8**)	The supplier's leagile production facilities, customization results, and centralized networks
9	Lead time (**C9**)	The supplier's delivery time of goods, delivery reliability, and location
10	Robustness (**C10**)	Supplier's reliability in tough situations including unlikely events
11	Eliminate muda (**C11**)	Supplier effectiveness on reducing and eliminating waste under lean principles
12	Automation and virtual enterprise (**C12**)	Supplier's advancements in automation and virtual reality to coordinate with sudden change in demand and supply
13	Market sensitivity (**C13**)	Risk degree, reputation, diversification
14	Uncertainty minimization (**C14**)	Supplier's level on minimizing uncertainty situations and uncertainty management system
15	Process integration (**C15**)	It delivers the impact of dynamic product development, marketing and sales

Table 2 Initial relationship matrix

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0	1	3	3	1	4	3	3	1	2	1	3	4	2	2
C2	2	0	4	4	2	4	3	3	2	4	2	3	4	3	3
C3	1	1	0	3	1	4	1	1	1	1	1	1	4	1	1
C4	1	1	1	0	1	4	1	1	1	1	1	1	4	1	1
C5	2	1	4	4	0	4	3	3	2	4	2	3	4	3	3
C6	1	1	1	1	1	0	1	1	1	1	1	1	4	1	1
C7	1	1	3	3	1	4	0	3	1	2	1	3	4	1	1
C8	1	1	3	3	1	4	1	0	1	2	1	3	4	1	1
C9	2	1	4	4	1	4	3	3	0	4	2	3	4	3	3
C10	1	1	3	3	1	4	1	1	1	0	1	1	4	1	1
C11	2	1	4	4	1	4	3	3	1	4	0	3	4	3	3
C12	1	1	3	3	1	4	1	1	1	2	1	0	4	1	1
C13	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
C14	1	1	3	3	1	4	3	3	1	2	1	3	4	0	2
C15	1	1	3	3	1	4	3	3	1	2	1	3	4	1	0

6 Discussion and managerial implications

This section combines two parts: our discussion of obtained results and the managerial implications of the study. First, the results are discussed through a vigorous comparison to the results obtained from the existing literature. Then, we provide the findings from discussions with case decision makers and field experts. Based on these elements, recommendations and implications of the study are summarized. Figure 2 shows the influential graph among the collected common criteria. This diagraph shows the influence among common leagile criteria, from which it can be clearly understood that 'Quality' (**C2**) is the most influential criteria and 'Market sensitivity' (**C13**) is the least influential criteria in terms of leagile based supplier selection. However, the influential order of remaining criteria is as follows: C2 > C5 > C9 > C11 > C1 > C14 > C15 > C7 > C8 > C12 > C10 > C3 > C4 > C6 > C13.

The diagraph can be divided into two groups, the cause group and the effect group. Criteria that influence other criteria are placed in the cause group, and the criteria that are influenced by other criteria are placed in the effect group. In total, nine criteria (**C2**, **C5**, **C9**, **C11**, **C1**, **C14**, **C15**, **C7**) belong in the cause group and seven criteria (**C8**, **C12**, **C10**, **C3**, **C4**, **C6**, **C13**) belong in the effect group. While comparing the results with the existing studies, it can be seen that this result is fully supported by earlier studies. Despite that quality is a conventional criterion, it still holds top position because of its priority towards a company's competitive advantage. In the earlier sections, it has been clearly discussed that this consideration of leagile supplier selection is to enhance the competitive advantage, so it is fitting that quality holds the top position of influential criteria. The need for a company to emphasize competitive advantage is acknowledged in several studies (see Ding et al. 2019; Powell 1995; Elshaer and Augustyn 2016).

In contrast, market sensitivity holds the least influential criterion. That finding may seem odd, but if we explore more, it can be seen that if the supplier is well-versed in uncertainty minimization (**C14**) and works to address service level and customer

Table 3 Normalized direct-relationship matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.0000	0.0179	0.0536	0.0536	0.0179	0.0714	0.0536	0.0536	0.0179	0.0357	0.0179	0.0536	0.0714	0.0357	0.0357
C2	0.0357	0.0000	0.0714	0.0714	0.0357	0.0714	0.0536	0.0536	0.0357	0.0714	0.0357	0.0536	0.0714	0.0536	0.0536
C3	0.0179	0.0179	0.0000	0.0536	0.0179	0.0714	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0714	0.0179	0.0179
C4	0.0179	0.0179	0.0179	0.0000	0.0179	0.0714	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0714	0.0179	0.0179
C5	0.0357	0.0179	0.0714	0.0714	0.0000	0.0714	0.0536	0.0536	0.0357	0.0714	0.0357	0.0536	0.0714	0.0536	0.0536
C6	0.0179	0.0179	0.0179	0.0179	0.0179	0.0000	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0714	0.0179	0.0179
C7	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0000	0.0536	0.0179	0.0357	0.0179	0.0536	0.0714	0.0179	0.0179
C8	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0179	0.0000	0.0179	0.0357	0.0179	0.0536	0.0714	0.0179	0.0179
C9	0.0357	0.0179	0.0714	0.0714	0.0179	0.0714	0.0536	0.0536	0.0000	0.0714	0.0357	0.0536	0.0714	0.0536	0.0536
C10	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0179	0.0179	0.0179	0.0000	0.0179	0.0179	0.0714	0.0179	0.0179
C11	0.0357	0.0179	0.0714	0.0714	0.0179	0.0714	0.0536	0.0536	0.0179	0.0714	0.0000	0.0536	0.0714	0.0536	0.0536
C12	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0179	0.0179	0.0179	0.0357	0.0179	0.0000	0.0714	0.0179	0.0179
C13	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0179	0.0000	0.0179	0.0179
C14	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0536	0.0536	0.0179	0.0357	0.0179	0.0536	0.0714	0.0000	0.0357
C15	0.0179	0.0179	0.0536	0.0536	0.0179	0.0714	0.0536	0.0536	0.0179	0.0357	0.0179	0.0536	0.0714	0.0179	0.0000

Table 4 Total influence matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.0216	0.0365	0.0958	0.0992	0.0371	0.1318	0.0818	0.0847	0.0378	0.0689	0.0385	0.0877	0.1387	0.0597	0.0607
C2	0.0639	0.0251	0.1290	0.1335	0.0607	0.1541	0.0935	0.0968	0.0617	0.1157	0.0628	0.1002	0.1622	0.0863	0.0878
C3	0.0324	0.0302	0.0284	0.0820	0.0307	0.1089	0.0381	0.0395	0.0312	0.0406	0.0318	0.0409	0.1147	0.0351	0.0357
C4	0.0313	0.0292	0.0443	0.0284	0.0297	0.1052	0.0369	0.0381	0.0302	0.0392	0.0307	0.0395	0.1108	0.0339	0.0345
C5	0.0628	0.0420	0.1268	0.1312	0.0251	0.1515	0.0919	0.0951	0.0607	0.1137	0.0617	0.0985	0.1594	0.0848	0.0863
C6	0.0297	0.0277	0.0421	0.0436	0.0282	0.0333	0.0350	0.0362	0.0287	0.0373	0.0292	0.0375	0.1052	0.0322	0.0328
C7	0.0365	0.0341	0.0894	0.0925	0.0347	0.1229	0.0255	0.0790	0.0353	0.0643	0.0359	0.0818	0.1294	0.0396	0.0403
C8	0.0353	0.0329	0.0863	0.0894	0.0335	0.1188	0.0416	0.0255	0.0341	0.0621	0.0347	0.0790	0.1250	0.0383	0.0389
C9	0.0617	0.0412	0.1246	0.1290	0.0420	0.1488	0.0903	0.0935	0.0251	0.1117	0.0607	0.0968	0.1567	0.0833	0.0848
C10	0.0335	0.0312	0.0820	0.0849	0.0318	0.1128	0.0395	0.0409	0.0323	0.0245	0.0329	0.0423	0.1187	0.0363	0.0370
C11	0.0607	0.0405	0.1224	0.1267	0.0412	0.1463	0.0888	0.0919	0.0420	0.1098	0.0251	0.0951	0.1540	0.0819	0.0833
C12	0.0341	0.0318	0.0834	0.0863	0.0323	0.1147	0.0402	0.0416	0.0329	0.0600	0.0335	0.0255	0.1208	0.0370	0.0376
C13	0.0282	0.0263	0.0400	0.0414	0.0268	0.0483	0.0333	0.0344	0.0272	0.0354	0.0277	0.0356	0.0333	0.0306	0.0311
C14	0.0385	0.0359	0.0941	0.0974	0.0365	0.1295	0.0804	0.0832	0.0371	0.0677	0.0378	0.0862	0.1363	0.0242	0.0597
C15	0.0378	0.0352	0.0925	0.0958	0.0359	0.1272	0.0790	0.0818	0.0365	0.0665	0.0371	0.0847	0.1339	0.0410	0.0242

Table 5 Sum of rows and columns

	ri	si	ri + si	ri − si
C1	1.080307	0.607837	1.688143	0.47247
C2	1.433434	0.499786	1.933221	0.933648
C3	0.720122	1.281236	2.001359	− 0.56111
C4	0.661813	1.36128	2.023093	− 0.69947
C5	1.391479	0.526098	1.917577	0.86538
C6	0.578722	1.754229	2.332951	− 1.17551
C7	0.941082	0.895769	1.836851	0.045314
C8	0.875283	0.962287	1.83757	− 0.087
C9	1.350246	0.552872	1.903118	0.797374
C10	0.780478	1.017197	1.797675	− 0.23672
C11	1.309725	0.580115	1.88984	0.729609
C12	0.811714	1.031139	1.842853	− 0.21943
C13	0.499786	1.899188	2.398974	− 1.3994
C14	1.044439	0.744095	1.788534	0.300345
C15	1.00919	0.774693	1.783883	0.234497

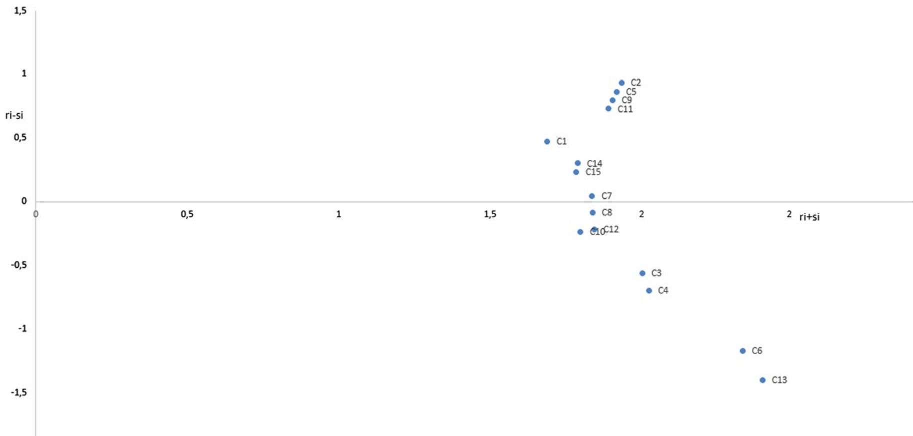

Fig. 2 Causal influence diagram for leagile criteria

satisfaction (**C5**), there is little need to think of market sensitivity. However, because both (**C14**) and (**C5**) rank above criterion (**C13**), it stands as less influential. In addition, in the literature, no previous study has mentioned the concern of market sensitivity in the performance of leagile supply chains. Next to quality (**C2**), service level and customer satisfaction (**C5**) holds the top position in the cause group due to the objective of leagile, which motivates a supplier to reach the right product, at the right time, at the right cost to the end consumer.

Once the results were compared with existing literature for examination of conceptual errors, the same was sent to the field experts who joined the 1-day workshop. Simultaneously, the results were shown to the industrial case managers. Three managers work with the supply chain department; one of those managers has more than 25 years of experience, and the other two managers have nearly 10 years. This difference in experience is prominently reflected in the decision makers' discussion sessions. First, all three managers accept these results, but some contradictory perspectives were introduced by the managers during the discussions. Some contradiction emerged among three managers; the two less experienced managers' viewpoints are similar but differ slightly from the elder manager's perspective. For instance, the senior manager did not have a strong conviction on sourcing (subsuppliers), whereas the other two managers are more keen towards the sourcing operations of the suppliers. This suggests that recent generation practitioners are more focused on whole supply chain rather than considering only first tier suppliers. In addition, automation and virtual enterprise were not considered comfortable by the senior manager, but the other two managers were eager to explore new technologies including IoT, block chain, and other methods to assist with supplier selection. However, the final output confirms that all results give a better understanding to supply chain managers regarding the leagile supplier selection process. This will lead them to approach their top level managers to convince and consider the leagile criteria in supplier selection.

While this study provides many valuable contributions towards the scientific relevance and practitioners' perspectives, some of our key contributions are: (i) this study provides the insights of influential leagile criterion and other influences among criteria, by which managers can give weightage to the relevant influential criteria while selecting the supplier rather than focusing on other irrelevant/less influence criteria. This could prevent the company from choosing the wrong suppliers. (ii) Based on the proposed framework, in the future, an '**n**' number of suppliers may be selected with more or fewer criteria from the collected common criteria based on the requirements. (iii) This study provides better understanding among the case decision managers regarding the significance of leagile in Chinese textile sectors.

7 Conclusion

Due to increasing pressures from customers and various stakeholders, companies started to integrate various strategies to maintain their competitive advantages in the global business markets. Among these strategies, lean and agile gained more attention due to their high positive effect on firm's performance. This study considers one of the effective processes of supply chain, supplier selection, with the focus of leagile. The common leagile criteria for supplier selection were collected from various sources including primary and secondary data. The collected common criteria were further evaluated for identifying the most and least influential leagile criteria for supplier selection. To achieve the objective, a model framework was proposed and the same applied in the case industry, which is a leading textile manufacturing industry located in China and a world leader/exporter of textiles. Among collected 15 criteria, quality (**C2**) was identified as the most influential criterion and market sensitivity (**C13**) was identified as the least influential criterion. The relevant validations and suggestions based on the obtained results has been given in corresponding sections. However, while this study presents significant contributions towards both science and society, it is still not exempt from limitations. The major limitation of this study is the lack of statistical response. This study adopts the case study methodology by analyzing a single case, but in a nation like China, a vast number of responses from textile industries were needed to generalize the obtained results to all Chinese textile manufacturing sectors. This limitation can be resolved in the next level of research, so if future studies consider this research as a pioneering work, the extension can be made with different provinces and with an effort to bring in a high number of statistical responses and also combined with resilience (Suifan et al. 2019).

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