

# Supplier Selection: A Lean-Agile (Leagile) Approach

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## Abstract

This study develops an integrated step by step approach for Lean-Agile (Leagile) supplier selection of automotive manufacturing companies. Although the concepts of Lean Manufacturing (LM) and Agile Manufacturing (AM) have been vastly discussed in previous literature, Leagile manufacturing strategy has been less examined, especially linked with supplier selection process. While agility is defined as the subsequent step of leanness, Leagility can consider both leanness and agility concurrently. In this regard, Leagile supplier selection aims to include both lean and agile criteria in supplier selection process. This study has been completed in three linked phases as follows. Firstly, a literature review is conducted to extract the most frequent criteria of supplier selection. Secondly, an Analytic Hierarchy Process (AHP) is applied to determine the most important Leagile supplier selection criteria. Finally, a Fuzzy Analytic Hierarchy Process (FAHP) is applied for the aim of Leagile supplier selection process of an automotive manufacturing company. According to obtained results, the output of this research can assist production managers to have the benefit of both lean and agile strategies in supplier assessment process.

## Keywords

Lean Manufacturing (LM), Agile Manufacturing (AM), Leagile Manufacturing, Supplier Selection, Automotive Industry

## 1. Introduction

Supply Chain (SC) and Supply Chain management (SCM) have been vastly investigated in recent years (Chopra and Meindl, 2007). As a common definition, SC includes a set of components which are linked to change raw materials to final products and deliver them to final customers in a specific time, location, and with an acceptable quality. There are many things linked with this process including monetary flow, product flow, information flow, reverse flow, and many other flows that are important to be managed. In this regard, SCM aims to handle the management process of all these components and flows simultaneously. As discussed, a SC comprises many components. These components include but not limited to suppliers, manufacturers, distributors, retailers and customers. Among all these components, suppliers play a more significant role as they provide raw materials, semi-finished products and other requirements of manufacturers. Therefore, supplier selection is an important issue of any supply chain seeking for success in today's competitive markets (Galankashi et al., 2016 a; Hashemzahi et al., 2020).

Supplier selection is the process of choosing best provider to purchase raw materials, components, semi-finished items and many other requirements which are used in production process. Supplier selection process has been occurred as a common activity of manufacturers from many years ago. The old style of supplier selection process mainly includes cost-based investigation of suppliers (Galankashi et al., 2013). In other words, previously, companies used to apply cost related measures to assess their suppliers. In this regard, the main competition of the suppliers was based on cost related issues. A supplier providing cheap raw material, components or semi-finished products could easily win the market as it was very important for the companies to decrease their costs as much as possible. However, this process was changed once the competition increased in the market. In other words, with the growth of economies and advancement of the technology, many companies started to improve their quality. The quality improvement process

needs many requirements as a high quality product needs high quality raw material, skilled workers, high-technology machines and a proper production planning. In this regard, the sole supplier selection criteria of cost was combined with quality related performance assessment metrics to be used in supplier selection process. With the advent of manufacturing strategies, each manufacturing supply chain adopted its specific strategy. In other words, as the ownership of supply chain was more integrated, the overall supply chain strategy was replaced with different strategies of each chain (Galankashi and Helmi, 2016). In this regard, many supply chains were constructed, designed, re-designed and planned based on their adopted manufacturing strategies. There are numerous manufacturing strategies available in the literature. These strategies comprise but not restricted to Lean Manufacturing (LM), Agile Manufacturing (AM), Leagile Manufacturing, Sustainable Manufacturing (SM), Green Manufacturing (GM) and many others (Gunasekaran, 1998; Hashemzahi et al. 2020; Galankashi et al., 2020a).

As discussed above, many manufacturing supply chains changed the distinct strategies of each chain to an integrated overall supply chain strategy. However, other strategies were still attractive as they provided some chances for more improvement. In other words, while a company might be lean in its production planning, it might be interested to be agile in its transportation. In addition, being lean means the company can go one step beyond to touch the agility requirement. However, there are many companies which are interested in using both strategies simultaneously. In this regard, the Leagile supply chain strategy can be a winning approach as it includes both lean and agile requirements. In other words, Leagility makes the benefits of both lean and agile supply chain strategies to be applied in SCM. As an important concern of all supply chain managers, supplier selection process can be also linked with Leagile supply chain strategy (Li et al., 2020). Therefore, companies can develop the required supplier assessment criteria to be applied in Leagile supplier selection process.

Although leanness, agility, Leagility and its related concepts and theories have been examined in previous studies (Galankashi and Helmi, 2017), the Leagility philosophy is less examined in conjunction with supplier selection process. Furthermore, almost all of the previous studies conducted on Leagility have provided its necessities, requirements, framework and neglected to provide its required supplier assessment criteria. There are some assessment tools to assess the leagility of manufacturing companies. Though, the mainstream of these assessment tools have used some measures to check the accordance of companies with Leagility philosophy. In this regard, investigating the literature to determine Leagile indicators, developing Leagile supplier selection criteria, and its supplier assessment process is beneficial for managers, practitioners and researchers who are interested in Leagile supplier selection process. As mentioned, while lean and agile supplier selection, have been separately investigated in previous literature, Leagile supplier selection is less examined. This is mainly due to the fact that this concept is not adequately known in many manufacturing companies, especially in developing countries. In addition, production managers still prefer to focus on cost minimization approaches instead of lean, agile or Leagile related concerns. However, when the market is not still adequately aware of the importance of these strategies, sole concentration on cost in the process of supplier selection is somehow justifiable in these companies. Therefore, Leagile supplier selection assists managers to focus on supplier assessment process and consider many important measures such as cost, lead-time and quality.

## 1.1 Objectives

This study develops an integrated step by step approach for Lean-Agile (Leagile) supplier selection of automotive manufacturing companies. Though, as the major objective, this research has developed specific criteria of Leagile supplier assessment and a Multi-Criteria Decision Making (MCDM) approach for Leagile supplier selection process.

## 2. Literature Review

There are many manufacturing strategies available in the literature. These strategies are different as they have been developed in different periods of time. In other words, these strategies have been developed based on specific requirements of the time. For example, previously, companies need to increase their production quantity. In this regard, the mass production strategy was a good choice as it could help manufacturing companies to increase the quantity of their production and take a bigger portion of the market. However, with the advent of manufacturing strategies and increasing concern over quality related issues, many companies changed their attitude toward manufacturing philosophy. In other words, while cost and revenue were still important in all companies, they started to improve their

quality, service level, lead-time and many other important issues to absorb more customers and a bigger portion of the market.

As a famous manufacturing strategy, LM has been vastly investigated in previous literature (Rezaei et al., 2020; Galankshi et al., 2020a). In addition, it has been successfully implemented in many manufacturing companies. The LM strategy was firstly developed by two Japanese engineers Taichi Ohno and Eiji Toyoda at Toyota Company. There are many issues linked with LM philosophy. However, waste elimination is the main concern of companies that are applying LM within their production system. Among different wastes of a production line, lean wastes include transportation, inventory, motion, waiting, over processing, overproduction, and defects. Following to the development process of LM, the book written by Womack et al. (1991) entitled “The machine that changed the world” showed how older manufacturing strategies such as mass production are different from Toyota Production System (TPS). In addition, according to this book, LM philosophy is a combination of TPS and Ford manufacturing style.

Following to LM philosophy, Agile Supply Chain Strategy (ASCS) has been considered as a substitute of leanness. In other words, previous literature has recommended to apply agile manufacturing strategy once the leanness is achieved by the companies. According to Mason-Jones et al. (2000), once the leanness is achieved by a supply chain it should struggle for agility. In other words, according to this research, agility is the ultimate objective of a supply chain and the leanness should be forgotten once the agility is attained. However, although leanness and agility are different, they sound similar and comparable for many managers. This is mainly due to the fact that incomparable to leanness, the agility is not deeply investigated in previous literature. While the LM philosophy is known with its famous manufacturing company Toyota, there is not a famous case study to promote agility. In this regard, many managers think agility and leanness as the same things. However, they are not. While LM aims to answer the problem of limited resources with no or few quantity of waste, conversely, agile manufacturing strategy aims to handle the complication which is linked with volatile markets. In this regard, according to Van Hoek et al. (2001), a supply chain should be agile to handle both unpredictability and variation of the markets.

More related to Leagility, as discussed, there are many companies which are seeking to have the benefits of both LM and AM. In this regard, Leagile supply chain strategy has been introduced to have the benefit of both lean and agile paradigms. According to Naylor et al. (1999), lean and agile models should be integrated to shape total supply chain strategy. To do so, this study has recommended to apply the concept of Order Penetration Point (OPP) which is also known as Decoupling Point (DP). In addition, this research has recommended to consider market knowledge when the companies are mixing lean and agile strategies. More related to supplier performance, according to Frohlich and Westbrook (2001), the performance of manufacturing company is influenced by their suppliers and customers. According to previous literature, each supply chain strategy has its specific requirements. For example, according to Li and O'Brien (2001), there is a specific relation between different metrics of each supply chain strategy. In this regard, any supply chain should be aware about its required Key Performance Indicators (KPIs). Therefore, it is critical for a supply chain to apply these KPIs in its different processes. As discussed, supplier selection process is an important concern of all manufacturers. In this regard, for a supply chain to consider both leanness and agility benefits in its supplier selection process, it is critical to apply the most important criteria of Leagile supply chain strategies. In other words, as previous literature has concentrated on applying less but fit measures in performance measurement, strategy selection and supplier assessment (Hemmati et al., 2018), it is necessary to develop specific criteria which are applicable for Leagile supplier selection process.

The current available literature on supplier selection is vast. In this regard, there are many studies published in this area. In addition, there are numerous criteria which are suggested in previous literature to be used in supplier selection process. As an impossible activity, no company can apply all these measures to assess its suppliers. This is mainly due to the fact that applying all available supplier selection criteria is very costly. In addition, many of these criteria are similar and applying them in supplier selection process is a type of waste as it increases the redundancy. Therefore, according to previous literature, applying the specific supplier selection criteria is more recommended. This research has developed the specific supplier selection criteria to be used in Leagile supplier selection process. Table 1 provides a summary of previous study. This table highlights more frequent applied supplier selection criteria developed in previous literature.

**Table 1.** Supplier selection criteria

Author	Year	Findings	Applied Criteria
Chang et al.	2011	Fuzzy approach to develop supplier selection criteria	<ul style="list-style-type: none"> <li>• Product quality</li> <li>• Stable delivery of goods</li> <li>• Reaction to demand change in time</li> <li>• Service</li> <li>• Product price</li> <li>• Delivery performance</li> <li>• Technology ability</li> <li>• Production capability</li> <li>• Financial situation</li> <li>• Lead-time</li> </ul>
Galankashi et al.	2013	Supplier selection based on different supply chain strategies	<ul style="list-style-type: none"> <li>• Lean manufacturer's supply chain strategy</li> <li>• Financial perspective</li> <li>• Customer perspective</li> <li>• Internal business perspective</li> <li>• Learning and growth perspective</li> <li>• Determinants under agile manufacturer's supply chain strategy</li> </ul>
Azadnia et al.	2015	Sustainable supplier selection and order allocation	<ul style="list-style-type: none"> <li>• Cost</li> <li>• Quality</li> <li>• Delivery</li> <li>• Loyalty</li> <li>• Technical capability</li> <li>• Environmental management system</li> <li>• Pollution</li> <li>• Green house emission</li> <li>• Occupational health and safety management system</li> <li>• Worker safety and labor health</li> <li>• Training education and Community development</li> </ul>
Galankashi et al. (a)	2016	Supplier selection in automotive industry	<ul style="list-style-type: none"> <li>• Financial perspective</li> <li>• Customer perspective</li> <li>• Internal business perspective</li> <li>• Learning and growth perspective</li> </ul>
Galankashi et al. (b)	2016	Lean supplier selection	<ul style="list-style-type: none"> <li>• Cost</li> <li>• Quality</li> <li>• Lead time</li> <li>• Service level</li> </ul>
Galankashi et al. (c)	2016	Agile supplier selection	<ul style="list-style-type: none"> <li>• Virtual Enterprise</li> <li>• Market sensitivity</li> <li>• Process Integration</li> <li>• Network based Supply</li> </ul>

As a summary of discussed literature presented in this section, based on findings of previous studies, it is essential to apply the specific supplier selection criteria in different supply chains. In other words, a lean supply chain should use lean supplier selection criteria while an agile or a Leagile supply chain should also apply their specific supplier selection criteria. Therefore, the majority of previous studies on this topic has recommended to integrate supply chain strategy and supplier selection criteria. However, as there are different criteria to be applied in supplier selection process, it is necessary to develop the specific supplier selection criteria of each manufacturing strategy. To fill this

gap, this research has applied the most frequent supplier selection criteria of the previous literature to assess their potentiality to be applied in Leagile supplier selection process. The developed methodology and findings of this research is entirely practical as it has been effectively practiced in a real case study from Iranian automotive industry.

**Table 1.** Continued

Author	Year	Findings	Applied Criteria
Abdel-Basset et al.	2018	An integrated approach for developing supplier selection criteria	<ul style="list-style-type: none"> <li>• Cost</li> <li>• Quality</li> <li>• Time delivery</li> <li>• Innovation</li> <li>• Reputation</li> <li>• Response to customers</li> <li>• Location</li> </ul>
Sinha & Anand	2018	Sustainable supplier selection index	<ul style="list-style-type: none"> <li>• Technological</li> <li>• Compatibility</li> <li>• Social acceptability</li> <li>• Economy</li> <li>• Environment</li> <li>• Quality</li> </ul>
Abdel-Baset et al.	2019	An integrated ANP and VIKOR for sustainable supplier selection	<ul style="list-style-type: none"> <li>• Cost of product</li> <li>• Revenue on product</li> <li>• Transportation cost</li> <li>• Vocational health and safety systems</li> <li>• Information</li> <li>• Ethical issues</li> <li>• Trash management</li> <li>• Green manufacturing</li> <li>• Green packing and labeling</li> </ul>
Konys	2019	Green supplier selection criteria	A set of clusters derived from Bibliometrics analysis.
Hashemzahi et al.	2020	Green supplier selection and order allocation in automotive industry	<ul style="list-style-type: none"> <li>• Unit purchasing</li> <li>• Price</li> <li>• Lead time</li> <li>• Environmental factor</li> </ul>
Rezaei et al.	2020	Lean supplier selection and order allocation in automotive industry	<ul style="list-style-type: none"> <li>• Quality</li> <li>• Cost</li> <li>• Delivery Performance</li> <li>• Flexibility</li> </ul>

### 3. Methods

This study develops an integrated step by step approach for Lean-Agile (Leagile) supplier selection of automotive manufacturing companies. In this regard, this study has been completed in three phases as follows. Different research steps are depicted in Figure 1.

#### 3.1 Phase one: Leagile supplier selection criteria

As discussed, there are numerous criteria to be applied in supplier selection process. As the quantity of these criteria is vast and companies cannot apply them simultaneously, it is necessary to use less but fit measures in the process of supplier assessment. As discussed, this research develops a Leagile supplier selection framework to be applied in automotive industry. In this regard, the general supplier selection criteria tabulated in Table 1 are applied

to determine their potentiality in Leagile supplier selection process. In other words, these criteria are more investigated to be applied in Leagile supplier selection process. Therefore, the output of this phase is already discussed in previous sections and is also tabulated in Table 1.

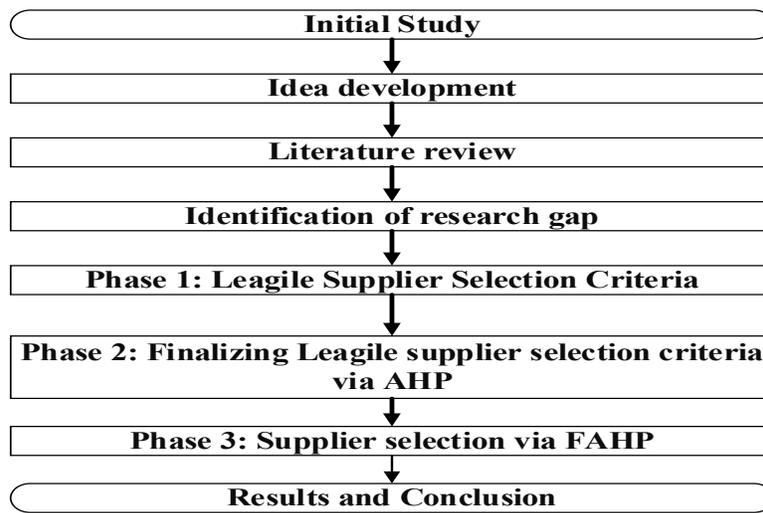


Figure 1. Research Steps

### 3.2 Phase two: Finalizing Leagile supplier selection criteria via AHP

Multi-Criteria Decision Making (MCDM) techniques are applied when decision makers face many criteria and alternatives. In this regard, these approaches assist them to handle the problem easily. These techniques have been successfully applied in previous literature (Galankashi et al. 2020b). More specifically, AHP has been successfully applied in many studies to determine supplier selection criteria, maintenance strategy selection criteria and etc. Following to previous phase, the AHP developed by Saaty (1988) is applied to finalize Leagile supplier selection criteria. The applied decision making hierarchy of this phase includes three levels as follows. The first level aims to finalize Leagile supplier selection criteria. Next, the second level includes three decision making criteria of measurability, application in Leagile environments and real application industry. Finally, Leagile potential supplier selection criteria are located at the third level of decision making hierarchy. As depicted in Figure 2, cost, quality, on-time delivery, service level, production method, financial status, technology and management are the potential supplier selection criteria to be ranked and applied in Leagile supplier selection process. Five experts who are familiar with supplier selection process in automotive industry have been asked to compare these criteria. The obtained results are presented in next sections.

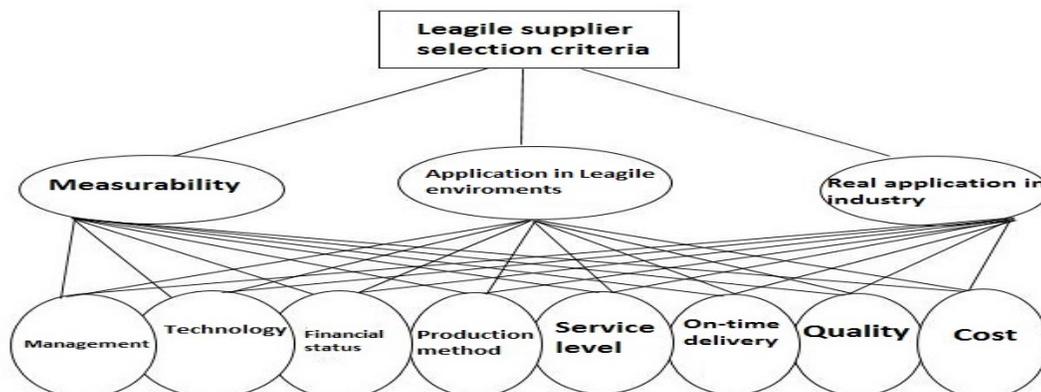


Figure 2. AHP structure to finalize Leagile supplier selection criteria

### 3.3 Phase three: Supplier selection via FAHP

According to previous literature, supplier selection is a MCDM techniques as different criteria should be simultaneously considered to assess the performance of suppliers. There are numerous MCDM techniques which are successfully applied in supplier assessment process. As a common approach, FAHP developed by Chang (1996) has been applied in this research. The applied equations and calculations are available in Chang (1996). Similar to AHP, FAHP also includes a hierarchical structure. In other words, as discussed in previous section, AHP and its AHP-related approaches such as FAHP include a goal, some criteria and alternatives. Figure 3 depicts the applied FAHP of this research. As shown in this Figure, there are three levels in this decision making structure. The first level includes the goal, the second level comprises the decision making criteria and the third level includes alternatives. Five most important supplier selection criteria extracted from previous phase have been applied to investigate and rank three potential supplies of an automotive manufacturing company. Three experts who are familiar with supplier selection process in automotive industry have been asked to compare these suppliers. The obtained results are presented in next sections.

### 4. Data Collection

An automotive manufacturing company from Iranian automotive industry has been chosen to be investigated. In addition, three potential suppliers have been selected to be ranked via the developed approach of this study. The considered case study produces automotive tires to be applied in final products of a bigger manufacturing company. In addition, considered suppliers are three Small and Medium-Sized Enterprises (SMEs) operating in Iranian automotive industry. The data collection process was completed using direct surveys to complete the research.

### 5. Results and Discussion

The attained results of this research are discussed in this section. As discussed in research methodology section, this study has been completed in three linked phases. Therefore, the obtained results are also discussed based on major outputs of each phase as follows. As discussed in research methodology section, this study develops a Leagile supplier selection methodology to be applied in a manufacturer from Iranian automotive industry. Therefore, as discussed in the first phase of research methodology section, the general supplier selection criteria tabulated in Table 1 are used to decide on their application in Leagile supplier selection process. So, these criteria were more explored to be applied in Leagile supplier selection process. The output of this phase is discussed in previous sections and is also tabulated in Table 1.

The second phase of this research aims to finalize Leagile supplier selection criteria via AHP. The applied decision making hierarchy of this phase was shown in Figure 2. As discussed, five experts who are familiar with supplier selection process of automotive industry have been asked to compare these criteria. As the first step of AHP, three decision making criteria of measurability, application in Leagile environments and real application in industry are mutually compared to determine their importance. This process is conducted to determine which decision making criterion is more important than others. To do so, the pairwise judgments of experts are aggregated and tabulated in Table 2.

**Table 2.** Pairwise comparison matrix of criteria

Aggregate judgments of experts	Real application industry	Application in Leagile environments	Measurability
Real application in industry	1.00	3.00	2.60
Application in Leagile environments	0.35	1.00	0.60
Measurability	0.42	1.80	1.00

As shown in Figure 2, eight criteria of cost, quality, on-time delivery, service level, production method, financial status, technology and management have been selected to be ranked and applied in Leagile supplier selection process. In addition, five experts from automotive industry have been asked to compare these criteria. Therefore, similar to previous phase, all these criteria are separately compared based on measurability, application in Leagile environments and real application in industry. To do so, the pairwise judgments of experts are aggregated and tabulated in Tables 3-5.

**Table 3.** Pairwise comparison matrix of criteria based on real application in industry

<b>Real application in industry</b>	<b>Cost</b>	<b>Quality</b>	<b>On-time delivery</b>	<b>Service level</b>	<b>Production method</b>	<b>Financial status</b>	<b>Technology</b>	<b>Management</b>
<b>Cost</b>	1.00	2.60	2.00	4.00	3.20	5.40	4.60	6.80
<b>Quality</b>	0.47	1.00	2.80	2.00	3.80	3.20	5.20	4.40
<b>On-time delivery</b>	0.50	0.37	1.00	2.60	1.80	3.80	3.20	5.20
<b>Service level</b>	0.26	0.50	0.47	1.00	3.40	1.80	4.00	2.80
<b>Production method</b>	0.33	0.30	0.60	0.31	1.00	2.80	1.80	3.80
<b>Financial status</b>	0.20	0.33	0.30	0.60	0.37	1.00	2.60	2.00
<b>Technology</b>	0.23	0.21	0.33	0.26	0.60	0.47	1.00	3.00
<b>Management</b>	0.15	0.25	0.21	0.47	0.30	0.50	0.33	1.00

**Table 4.** Pairwise comparison matrix of criteria based on application in Leagile environments

<b>Application in Leagile environments</b>	<b>Cost</b>	<b>Quality</b>	<b>On-time delivery</b>	<b>Service level</b>	<b>Production method</b>	<b>Financial status</b>	<b>Technology</b>	<b>Management</b>
<b>Cost</b>	1.00	1.00	2.60	2.00	1.40	2.80	2.60	1.40
<b>Quality</b>	1.00	1.00	2.60	2.60	1.00	2.60	1.00	2.60
<b>On-time delivery</b>	0.40	0.40	1.00	1.00	0.80	2.00	1.40	2.00
<b>Service level</b>	0.50	0.40	1.00	1.00	1.00	0.40	0.43	1.00
<b>Production method</b>	0.80	1.00	1.40	1.30	1.00	2.40	2.00	2.60
<b>Financial status</b>	0.38	0.40	0.50	2.60	0.43	1.00	0.43	3.40
<b>Technology</b>	0.42	1.00	0.80	2.40	0.63	2.40	1.00	3.40
<b>Management</b>	0.87	0.40	0.50	1.00	0.48	0.30	0.30	1.00

**Table 5.** Pairwise comparison matrix of criteria based on measurability

Measurability	Cost	Quality	On-time delivery	Service level	Production method	Financial status	Technology	Management
<b>Cost</b>	1.00	2.20	2.80	3.00	3.00	3.00	2.80	4.00
<b>Quality</b>	0.47	1.00	2.00	2.00	1.60	2.20	2.00	4.00
<b>On-time delivery</b>	0.37	0.50	1.00	1.00	0.45	2.00	0.25	3.20
<b>Service level</b>	0.35	0.50	1.00	1.00	0.47	0.33	0.50	1.70
<b>Production method</b>	0.33	0.70	2.80	2.20	1.00	2.40	1.20	2.00
<b>Financial status</b>	0.33	0.47	0.50	3.00	0.43	1.00	1.00	3.60
<b>Technology</b>	0.38	0.50	4.00	2.00	0.90	1.00	1.00	3.00
<b>Management</b>	0.25	0.25	0.32	0.80	0.50	0.28	0.33	1.00

Finally, using the AHP, the pairwise comparison matrix of criteria and all three pairwise comparison matrices of alternatives were entered into Microsoft Excel 2013 software to determine final weights of Leagile supplier selection criteria. As tabulated in Table 6, cost, quality, on-time delivery, production method and service level are the most important leagile supplier selection criteria.

**Table 6.** Final weights of Leagile supplier selection criteria

Criteria	Weight	Ranking
<b>Cost</b>	0.27	1
<b>Quality</b>	0.19	2
<b>On-time delivery</b>	0.13	3
<b>Service level</b>	0.10	5
<b>Production method</b>	0.11	4
<b>Financial status</b>	0.08	6
<b>Technology</b>	0.08	7
<b>Management</b>	0.04	8

As discussed in research methodology section, Figure 3 depicts the applied FAHP of this research. In other words, five supplier selection criteria with highest weights tabulated in Table 6 have been selected as final Leagile supplier selection criteria. Three experts who are familiar with supplier selection process in automotive industry have been asked to compare three potential suppliers of an automotive manufacturer. Similar to AHP, Table 7 tabulates the aggregate pairwise comparison matrix of all three experts.



**Figure 3** Leagile supplier selection decision hierarchy

**Table 7.** Aggregate pairwise comparison matrix of criteria based on all three experts

Aggregate values	Cost	Quality	On-time delivery	Production method	Service level
Cost	(1,1,1)	(1,1,1)	(0.66,1,1.33)	(0.83,1.33,1.83)	(0.83,1.33,1.83)
Quality	(1,1,1)	(1,1,1)	(0.5,1,1.5)	(0.83,1.33,1.83)	(0.5,1,1.5)
On-time delivery	(0.77,1,1.66)	(0.66,1,2)	(1,1,1)	(0.66,1,1.33)	(0.66,1,1.33)
Production method	(0.55,0.77,1.33)	(0.55,0.77,1.33)	(0.77,1,1.66)	(1,1,1)	(0.5,0.66,1)
Service level	(0.55,0.77,1.33)	(0.66,1,2)	(0.77,1,1.66)	(1,1.5,2)	(1,1,1)

As shown in Figure 3, three potential suppliers have been selected to be ranked by Leagile supplier selection criteria. In addition, three experts from automotive industry have been asked to compare these alternatives. Therefore, similar to previous phase, all these suppliers are separately compared based on cost, quality, on-time delivery, production method, and service level. To do so, the pairwise judgments of experts are aggregated and tabulated in Tables 8-12.

**Table 8.** Aggregate pairwise comparison matrix of suppliers based on cost

Cost	Supplier Y	Supplier B	Supplier G
Supplier Y	(1,1,1)	(1,1,1)	(0.5,1,1.5)
Supplier B	(1,1,1)	(1,1,1)	(0.5,1,1.5)
Supplier G	(0.66,1,2)	(0.66,1,2)	(1,1,1)

**Table 9.** Aggregate pairwise comparison matrix of suppliers based on quality

Quality	Supplier Y	Supplier B	Supplier G
Supplier Y	(1,1,1)	(1,1,1)	(0.5,1,1.5)
Supplier B	(1,1,1)	(1,1,1)	(0.5,1,1.5)
Supplier G	(0.66,1,2)	(0.66,1,2)	(1,1,1)

**Table 10.** Aggregate pairwise comparison matrix of suppliers based on on-time delivery

On-time delivery	Supplier Y	Supplier B	Supplier G
Supplier Y	(1,1,1)	(0.77,1,1.66)	(0.5,1,1.5)
Supplier B	(0.66,1,1.33)	(1,1,1)	(0.66,1.16,1.66)
Supplier G	(0.66,1,2)	(0.60,0.88,1.66)	(1,1,1)

**Table 11.** Aggregate pairwise comparison matrix of suppliers based on production method

Production method	Supplier Y	Supplier B	Supplier G
Supplier Y	(1,1,1)	(0.83,1,1.16)	(0.66,1,2)
Supplier B	(0.88,1,1.33)	(1,1,1)	(0.66,1,2)
Supplier G	(0.5,1,1.5)	(0.5,1,1.5)	(1,1,1)

**Table 12.** Aggregate pairwise comparison matrix of suppliers based on service level

Service level	Supplier Y	Supplier B	Supplier G
Supplier Y	(1,1,1)	(0.88,1,1.33)	(0.5,1,1.5)
Supplier B	(0.83,1,1.16)	(1,1,1)	(0.5,1,1.5)
Supplier G	(0.66,1,2)	(0.66,1,2)	(1,1,1)

Finally, using FAHP, the pairwise comparison matrix of criteria and all five pairwise comparison matrices of alternatives were entered into Matlab 2014b software to determine final weights of suppliers. As tabulated in Table 13, the weights of all suppliers are almost the same. However, supplier B has the highest weight compared to other two suppliers. Therefore, the final ranking of suppliers is supplier B, supplier y and supplier G, respectively.

**Table 13.** Final ranking of suppliers

Supplier	Supplier G	Supplier Y	Supplier B
Weight	0.3315	0.3327	0.3355
Ranking	3	2	1

## 6. Conclusion

This research developed an incorporated approach for Leagile supplier selection of automotive manufacturing companies. Firstly, a literature review was conducted to extract potential criteria. Secondly, an AHP was applied to determine Leagile supplier selection criteria. Finally, a FAHP was applied for Leagile supplier selection process of an automotive manufacturing company. While the research has provided a Leagile supplier selection framework, other researchers might apply the same methodology to develop other specific supplier selection frameworks. In addition, other MCDM techniques can be tested in Leagile supplier selection process.

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