Exploring the Academic–Industry Collaboration in Knowledge Sharing for Supplier Selection: Digitalizing the OEM

Ayon Chakraborty, Jinil Persis, and Kamran Mahroof

Abstract—**Increasing reliance on digital technologies has led to a significant shift in how businesses operate, with many now relying heavily on digital platforms for effective planning, communication, sales, marketing, supply chain, and logistics management. In this context, knowledge sharing platforms enable academic–industry collaboration in which exchange of ideas, opinions, experience, and expertise brings collective intelligence in cooperative learning ecosystem thereby expediting decision making. However, establishing long-term commitment among the partners, allocation of time and resources for sharing tacit knowledge, collaboration among partners with different strategic priorities, and real-time knowledge sharing capabilities are essential for effective and rapid learning in knowledge sharing platforms. The present article will examine these benefits and challenges in knowledge sharing and its impact on supplier selection platforms in Asian automakers. The findings of this article will be helpful for researchers and practitioners intending to explore the role of cooperation in knowledge sharing and digital transformation amid competitive environment prevalent in the automotive industry. The potential supplier database is first examined for qualifying the capability requirements put forth in this article and further prioritized using a multicriteria decision-making technique and analytic hierarchy process. The article results reveal that the manufacturer has highly prioritized firms' financial transparency for supplier evaluation followed by the suppliers' cost control, quality control, and manufacturing capabilities. The article has significant theoretical and practical implications for developing robust supplier evaluation criteria for automobile industry and a digital ecosystem for original equipment manufacturers in making supplier related decisions.**

Index Terms—**Analytical hierarchy process (AHP), knowledge sharing, multicriteria decision-making (MCDM), supplier selection.**

I. Introduction

THE Asian Automotive sector operates in a unique and complex multitier supply chain environment [1]. Demand uncertainty factored with uneven growth, volatility, and aftersales support ripples more as deeper the automotive supply chain [2], [3]. Global automotive supply chains are often longer and wider as a typical automobile comprises more than 20 000 different components with close to 150 subassemblies/modules, which are sourced by an original equipment manufacturer (OEM) from many partners [4]. Also, automotive OEMs must adopt best practices to coordinate and align their supply chains to meet global standards. Due to evolving customer preferences, many unique parts and innovative product features are getting introduced and the lead time to design and develop these is becoming one of the important factors that determines the speed-to-market and offers a competitive edge in the global market [5]. Choosing suppliers who are strategically synergetic with the OEM's requirements plays a crucial role in meeting the aforesaid requirements [6]. Hence, it becomes the major responsibility of the sourcing team to carefully select and evaluate the capabilities of the suppliers for the benefit of the organization [7].

Due to increasing competition from global players, Asian OEMs are predominantly outsourcing the aggregates, systems, and components, that are not in the core competency of the OEM to reduce the manufacturing cost [8]. While top Asian Automotive OEMs strives to achieve profitability across various segments like two-wheelers, three-wheelers, passenger cars, commercial vehicles, tractors, we observed that the percentage of total material cost to the total operating revenue comes to around 50%–70% across various segments. Hence, reducing the total material cost is the most crucial for any automotive OEM to yield substantial profits without compromising quality, speed, and flexibility; thus, supplier selection is a complex multifaceted decision. While OEMs identify potential suppliers whose capability meets the aforementioned requirements, it is extremely important to ensure strategic fit among the partners for long-lasting alliance [9]. With the short product life cycle and changing customers' choices and priorities, automotive industry needs to focus on flexible and agile strategies to be responsive while efficient [10]. For this, OEMs need to build strategic partnerships with suppliers who can quickly respond to the rapidly changing market. While OEMs progress in consumerism, environmental responsibility is also critical to integrate ecofriendly perceptual attributes with their brand which should also be considered in evaluating manufacturer–supplier partnerships [11].

Supplier performance evaluation is critical to explore compatibility for having strategic partnership between buyers and

Manuscript received 16 January 2023; revised 5 March 2023; accepted 16 March 2023. Date of publication 5 April 2023; date of current version 23 April 2024. Review of this manuscript was arranged by Department Editor D. Cetindamar. *(Corresponding author: Ayon Chakraborty.)*

Ayon Chakraborty is with the Federation University, Ballarat, VIC 3353, Australia (e-mail: a.chakraborty@federation.edu.au).

Jinil Persis is with the Quantitative methods and Operations Management Area, IIM Kozhikode, Kerala 673570, India (e-mail: jinilpersis@gmail.com).

Kamran Mahroof is with the School of Management, University of Bradford, BD7 1DP Bradford, U.K. (e-mail: k.mahroof@bradford.ac.uk).

Digital Object Identifier 10.1109/TEM.2023.3260042

suppliers when they often independently have quality, cost, timeliness, or flexibility based competitive strategic priorities [12], [13]. The business strategic alignment of partners with OEM is essential to maximize the overall supply chain performance, which is a very challenging task in an automotive industry [14]. India's current supplier management system is more of qualitative factors that do not provide comprehensive guidance to the management for decision-making [15]. On the other hand, decision support systems incorporating mathematical models could not bring effective supply chain coordination as they could not handle multiple, often, contending qualitative and quantitative supplier selection criteria [16]. Hence, the decision support systems incorporating a suitable multicriteria decision-making (MCDM) method to evaluate strategic supplier partnerships on the basis of their capabilities on various aspects are essential in automotive industry [17].

There is a need to have a collaborative environment conducive to sharing knowledge among practitioners and academic researchers in developing a supplier selection framework for the automotive industry. Appropriate qualitative and quantitative factors that elucidate the performance of the suppliers are to be explored to properly make supplier evaluation and selection framework. We demonstrate this framework with the use of a case study in an Asian automaker, where the existing OEMs' supplier management system was not rightly aligned with the strategic view affecting supplier evaluation and selection. Therefore, this article aims to improve the decision support system and by incorporating multiple perspectives and criteria, the article also aims to categorize and measure suppliers based on their capabilities. The authors used an analytic hierarchy process (AHP) to establish the priority scales for supplier evaluation criteria based on the judgment of experienced practitioners on every influencing criteria pairs. The improved decision support system is used further to establish strategic partnerships with suppliers to involve a long-term collaborative relationship. Specifically, overlapping the strategic views of suppliers with that of the OEMs strengthens the customer relationship and enables the supply chain tackle demand uncertainty and respond rapidly to the evolving needs of the customers [18].

The rest of the article is organized as follows: The following section presents works related to recent frameworks introduced in supplier evaluation and selection. The section also presents the results of literature review analysis. Section III presents supplier assessment and preliminary selection process. Section IV presents the methodology. Section V presents the results of AHP. Section VI presents discussion on key findings and presents the proposed framework. Section VII presents conclusions and implications derived from the study for research and practice with limitations and future research directions.

II. Related Works

A. Supplier Selection in SMEs

Supplier evaluation of the small and medium enterprises (SMEs) are predominantly based on the compliance with quality, cost, and delivery requirement of the OEMs. However, factors related to flexibility, resilience, environment, health and safety, reputation, innovation, and technology are also to be evaluated to make strategic supplier choices [19], [20], [21]. The Asian SMEs contribute up to 45% of total manufacturing output, 17% of gross domestic product, and 40% of total workforce in India. The major challenge faced by SMEs is to achieve business sustainability amid the dynamics of supply and demand. Strong competition and invariably high demand in the global and local markets combined with economic pressure have pull down the market price of their products affecting their profitability and sustainability to a greater extent due to which employment generation of SMEs is greatly reduced in recent years [22], [23]. Many researchers developed procurement models to drive the sustainability of SMEs and attempted to understand the practices of the public procurement process from the OEM's standpoint [19], [20], [21]. Though cost and quality remain to be the foremost considerations in the supplier selection process with growing importance to sustainability, OEMs are considering looking for additional capabilities of SMEs. There is a need to have public procurement policy to stimulate SMEs' capabilities to achieve both competitiveness and sustainable goals [24], [25]. In 2018, Indian government has set an annual target to public buyers that at least 25% of their annual procurement must be made from SME sector. Percentage of public buyers' procurement in 2019 from SMEs rose to 26.32%, 30.18% in 2020 and 27.25% in 2021, which is effectively managed by mandatory online publishing of tenders, framing annual procurement plans, saving transaction cost especially for SMEs, relaxing prior experience mandates, generating reports of targets with disaggregated data, and frequent and regular vendor development programs [26]. Indian government also mandates 65% of locally manufactured parts and components to get qualified as a domestic vehicle as part of "Make in India" scheme. However, a comprehensive supplier selection framework for Asian Automotive giants incorporating multidimensional criteria is to be developed.

The most important issue in the supplier selection process is determining the appropriate decision-making criteria for choosing the right supplier [27], [28], [29]. The criteria for supplier selection evolve over time. For example, during the 1980s, price was considered a significant criterion and in the early 1990s, lead time to develop and responsiveness were included, followed by flexibility in the early 2000s and the requirement of multiple product quality dimensions like performance and reliability. The supply chain environment is predominantly characterized by political, economic, social, technological, legal, and environmental factors, which could also be considered for supplier selection [30], [31]. Therefore, a comprehensive analysis becomes essential to identify the elements of supplier performance. While quality, delivery, and cost remain the most crucial factors, the importance of associated criteria is enunciated vis-a-vis financial position, management culture, flexibility, innovation, research and development, availability of information and communication systems, capacity management, and technical capability. Literature highlights the need for sourcing models that consider factors relating to benefits, opportunities, costs, and risks [31]. Supplier selection has the vast potential of impacting the overall firm's performance [32]. Sharma and Joshi [32] investigated

Asian firms and had list down various supplier selection criteria resulted from the data collected through a comprehensive survey and the corresponding ratings were measured in grey numbers, and criteria were ranked accordingly. Out of 85 criteria considered, based on the survey results, 21 criteria crucial for supplier selection in the Asian Automotive industry are selected, which includes direct criteria like cost, quality, quality system adherence and compliance, reputation, delivery performance, financial position, technical capability, manufacturing capability, capacity management, warranty and claims, TS certification and other indirect criteria like relationship, trust, management culture, attitude, and geographical presence. It becomes essential for OEM to decide the appropriate supplier selection criteria. Taherdoost et al. [33] provide an overview of supply chain management, supplier selection, and evaluation criteria, and discuss various supplier selection methods that can be adopted by OEMs to achieve success and competitiveness. They also highlight the structured decision-making especially required under complex conditions in the presence of quantitative and qualitative data. Identification of appropriate decision-making criteria and proper choice of methods for supplier selection drive firms' competitiveness. While most of the studies investigated quality, delivery schedule, and value per unit cost offered by potential suppliers, along with these, criteria related to risk management, organizational, environmental, and social practices are also incorporated and relationship of the resultant sourcing decisions with operational performance and business success is demonstrated in U.K. based firm [12].

B. Impact of Multicriteria Decision-Making in Supplier Selection

Essentially, potential suppliers are identified based on their ability to meet the expected quality, cost, and delivery schedule, and then are evaluated based on several other capabilities that would enable them to be flexible, reliable, robust, and competitive [27]. While literature shows evidence of supplier selection based on a single criteria, these decisions are myopic and often suffers from poor buyer–supplier coordination and customer satisfaction [29]. Supplier evaluation and subsequent selection decision must be based on examining multiple criteria simultaneously that could be of qualitative or quantitative nature [28]. Moreover, today's purchase managers encounter evolving and conflicting criteria in a volatile and dynamic business environment. To develop an effective supplier evaluation and selection framework, one must identify the necessary and desirable supplier capabilities and a suitable method for investigating them. The evaluation criteria should be able to examine the strategic alignment of the suppliers that would enable long term commitment and win stakeholders' satisfaction. MCDM is a scientific approach to arrive at decisions when homogeneous alternatives compete with multiple heterogeneous criteria simultaneously [31]. In the last two decades, this is a widely used approach for addressing diversified business problems.

In [33], 60 different methods to solve MCDM problems are highlighted. We have observed that around 47% of the research articles employed AHP. This is because AHP evaluates the alternatives with a pairwise comparison of hierarchical criteria that includes both qualitative and quantitative criteria. The multilevel hierarchical structure of criteria is formed analytically with their relative importance. The supplier alternatives are prioritized based their capabilities with respect to criteria as per their hierarchical level. Many research studies involving MCDM approach focus on supplier selection and evaluation problem using AHP [12], [34]. Moreover, AHP follows a systematic problem-solving framework and is suitable for evaluating both individual and group preferences by synthesizing human judgments and recommends the most preferred alternative that suits the stated needs of the organization [35]. Furthermore, AHP asserts consistency in judgments and offers a feedback mechanism to adjust inconsistencies leading to right decisions [36]. So AHP is widely employed in supplier selection, provided, the criteria are independent of their alternatives [37]. However, enough data are required for an AHP to discover a hierarchical structure underpinning the criteria and all possible pairs of comparison criteria have to be evaluated before a final decision is arrived [38].

Recently, researchers have widely used a rough number-based compromise ranking method known as VIKOR to determine the weights of conflicting criteria. Zhou et al. [6] developed an integrated model for supplier selection that employs an extended VIKOR-based MCDM technique. This technique selects key outsourcing parts and an integer programming model to minimize the weighted combination of total quality-related costs, system reliability, delivery time, and customer complaints. Additionally, the model employs a genetic algorithm with a local search strategy to determine the weights. The authors demonstrate the effectiveness of this approach in improving strategic quality management by improving quality in key parts and selecting the best outsourcing supplier portfolio for a Chinese domestic automaker. Other researchers have also used VIKOR–AHP to generate solutions for the supplier selection problem, evaluating various criteria, and allowing the OEM to choose the most suitable supplier, as demonstrated in an Iranian automaker [31]. Recently, researchers have also focused on the sustainability aspect of supplier evaluation, using a strategy-aligned fuzzy simple multiattribute rating technique (smart) framework to evaluate potential cooperative and collaborative partners, considering criteria related to financial, technological, organizational, strategic, and performance aspects [39]. The use of an MCDM model can assist in structuring various criteria by assigning weightages to individual parameters.

C. Need for Digitalization in Supplier Selection

Digitalization enables more efficient and accurate evaluation of potential suppliers, automating time-consuming and error-prone tasks associated with traditional supplier selection processes through digital tools, such as electronic request for proposal platforms and supplier management software. These allow for real-time tracking and analysis of supplier performance data to make more informed decisions about supplier selection and relationship improvement [40], facilitate communication and information sharing between a company and potential suppliers, reducing misunderstandings, and increasing the chances of a successful outcome [41].

Digital tools, such as supplier management software, allow companies to collect and analyze real-time data on supplier performance, such as delivery times, quality levels, and compliance with regulations, to identify and address issues and improve performance [42]. Digitalization also allows companies to evaluate suppliers based on a broader range of criteria, such as sustainability, innovation, and corporate social responsibility, helping companies to identify suppliers better aligned with their values and goals and build long-term sustainable relationships [43]. Digitalization has become essential in supplier selection as it enables companies to make more data-driven decisions, leading to improved performance and tremendous success in the long term.

III. Supplier Assessment for Automakers

Previous articles about supplier evaluation assess three key factors of the supply chain: quality, cost, and delivery, apart from the manufacturing capability of the supplier [31]. Supply of raw materials as per the MRP/monthly production schedules with appropriate quality levels and organizing delivery at the right time becomes most crucial in the supply chain [44]. To ensure right processes with the lowest cost and highest levels of quality, the supplier should be equipped with adequate manufacturing capability. Broadly, the existing supplier evaluation system in automaking companies assesses the suppliers based on four capabilities: 1) manufacturing capability, 2) quality control capability, 3) cost control capability, and 4) delivery performance. Moreover, under each qualifying criteria, the suppliers are assessed, and corresponding compliances are recorded. The qualification of the suppliers in terms of their capabilities are determined based on the following formula:

$$\text{Qualification Level} = (\text{Number of processes qualified})/(\text{Total Number of qualifier concepts}). \quad (1)$$

Since supplier evaluation is one of the crucial decision-making processes in supply chain management of an OEM, it is important to assess suppliers based on a comprehensive set of criteria [28], [33], [45], [46]. A suitable supplier evaluation process would reduce raw material cost, increase profits, reduce time to introduce products into the market, improve customer satisfaction, and add competitive advantage to the OEM [12]. The conventional method lacks critical criteria for assessing the strategic fit of the suppliers, which may eventually lead to selection of poor choice which affects the performance of the OEM. The important part in supplier evaluation is choosing the right criteria with which supplier needs to be evaluated. While the traditional method of supplier selection criteria involving quality, cost, delivery, and manufacturing ability is relevant, other aspects of evaluation like technical capability, financial status, design, and development are highly required for better management and to establish strategic and cultural fit with OEM for automakers in today's competitive environment. Technical capability of suppliers in meeting the demands of OEM time to time ensures long-term partnerships that could withstand the test of time. The suppliers need to be agile and take less time to respond to the design changes and technological transformation happening at the buyers' end [28], [47]. Financial transparency and capability of the suppliers are very much essential to become order winners and establish a stable buyer–supplier relationships [12], [48]. Highly responsive design and development capability of supplier in a collaborative environment expedites the product releases and gives a competitive edge to the OEMs [49]. Awareness of the suppliers about the environmental and safety related policies and regulations of the buyers is also extremely important for bringing strategic fit among the dyad [46], [50].

TABLE I
Assessment Aspects From Literature and Domain Experience

Identifier	Qualifiers	References
MC	Manufacturing capability	[9]
QC	Quality control capability	[50]
DD	Design and development capability	[51]
TQM	Total quality management	[52]
OBC	Open book costing	[53]
DP	Delivery performance	[54]
FP	Financial performance	[48]
MCL	Management culture	[55]

Improved supplier evaluation is crucial for OEMs to scientifically identify the suppliers and remove the hidden cost drivers in its supply chain. With OEMs shifting its focus toward long term and sustainable supply chain, a supplier should possess many other capabilities not only related to capacity, cost, quality, and delivery performance. These enhanced supplier's capabilities can be categorized into various buckets as shown in Table I.

Now, these qualifier concepts are incorporated in the improved evaluation system. Also, we have modified the formula to evaluate the qualification of suppliers, i.e., we have replaced the current binary scoring system (yes or no for compliance and noncompliance, respectively) with three-point Likert scale, which will increase the reliability of the assessment model. It also facilitates better discrimination of the concepts measured. This scoring scheme ensures in-depth capability analysis of each concept and enable deriving more data as scale and allow us to calculate statistical parameters. Thus, the qualifying levels of all those eight capabilities is gauged for a sample supplier using the following formula and the results are presented in Table II

$$\text{Qualification Level} = \frac{\sum \text{Section wise Score}}{\sum \text{Total Score}}. \quad (2)$$

The suppliers of an OEM are evaluated based on this approach and a supplier database is developed in a knowledge sharing platform that evolves based on the inputs received from OEMs, researchers, and academicians. However, the average score obtained as 87.82% considers at the same level with equal importance, which is practically often otherwise. Hence, we determine the importance of these criteria and derive a hierarchical structure using AHP.

TABLE II
EVALUATION OF SCORES

Assessment aspects	FC* (five points)	# Minor NC* (three points)	# major NC* (one point)	Sectionwise Score	Section total score	Section wise capability %
MC	10	2	1	57	65	**87.69%**
DD	9	3	1	55	65	**84.62%**
QC	13	3	1	75	85	**88.24%**
TQM	11	2	0	61	65	**93.85%**
OBC	7	3	2	46	60	**76.67%**
DP	7	2	1	42	50	**84.00%**
FP	3	0	0	15	15	**100.00%**
MCL	12	3	1	70	80	**87.50%**
Average score →						87.82%

*FC – full compliance, NC – noncompliance.

		MC	DD	QC	TQM	OBC	DP	FP	MCL
		1	2	3	4	5	6	7	8
MC	1	1	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}
DD	2	$1/C_{12}$	1	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
QC	3	$1/C_{13}$	$1/C_{23}$	1	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}
TQM	4	$1/C_{14}$	$1/C_{24}$	$1/C_{34}$	1	C_{45}	C_{46}	C_{47}	C_{48}
OBC	5	$1/C_{15}$	$1/C_{25}$	$1/C_{35}$	$1/C_{45}$	1	C_{56}	C_{57}	C_{58}
DP	6	$1/C_{16}$	$1/C_{26}$	$1/C_{36}$	$1/C_{46}$	$1/C_{56}$	1	C_{67}	C_{68}
FP	7	$1/C_{17}$	$1/C_{27}$	$1/C_{37}$	$1/C_{47}$	$1/C_{57}$	$1/C_{67}$	1	C_{78}
MCL	8	$1/C_{18}$	$1/C_{28}$	$1/C_{38}$	$1/C_{48}$	$1/C_{58}$	$1/C_{68}$	$1/C_{78}$	1

Fig. 1. Pairwise judgment matrix.

IV. METHODOLOGY

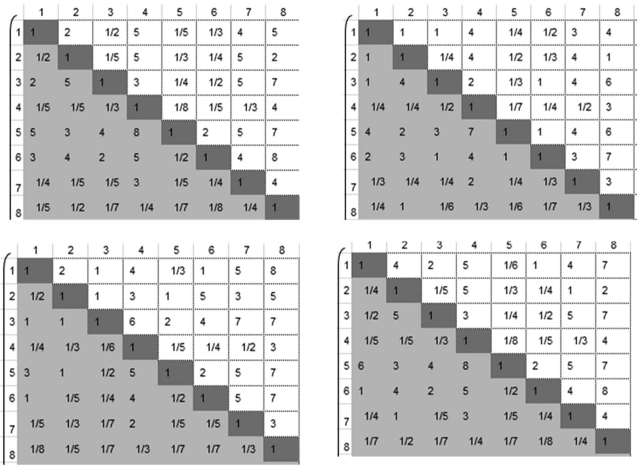
The article deals with supplier evaluation and selection using a knowledge sharing platform developed in a collaborative environment involving academicians and practitioners. This article has identified eight key capabilities (refer Table I) based on which suppliers are evaluated. To select a supplier which is strategically aligned and to establish a long-term commitment, we develop an MCDM model and assign different weightage to each capability and holistically rank the potential suppliers. We establish a hierarchical structure of supplier selection criteria using AHP and thereby we can visualize the relationship of various aspects of suppliers' capabilities. An expert team of respondents have to be carefully chosen and their judgments on all paired criteria are to be obtained. MCDM approach enables solving this complex supplier selection problem by systematizing the opinions, decision, and emotions of the decision maker into a structured environment [6], [31], [56]. A typical MCDM approach here leads to a preferred or optimal alternative $A^* \in A = \{A_1, \ldots, A_n\}$ among n alternatives and assigns normalized weights $w_j \; \forall j \in \{C_1, \ldots, C_8\}$ to criteria based on their relative importance [33]. The scales used for assessing judgments helps the decision-maker to blend the knowledge and experience intuitively and indicate the number of times a particular criterion dominates another criterion. The respondents were offered a series of pairwise comparison questions. The survey comprises of 28 questions. It includes assigning enough details on representing the problem, environment surrounding it, which helps in providing overall view of the various criteria and complex relationships between them, assist the decision-maker that criteria are not in same order of magnitude. The respondents were asked to assess the relative importance of two different criteria at a given point of time. The fundamental scale in comparison consists of verbal judgments, which ranges from equal to extreme. The corresponding numerical judgments are recorded as 1, 3, 5, 7, and 9 for equal, moderate, strong, very strong, and extreme variables. The values 2, 4, 6, and 8 are used to represent the intermediate values. The respondents' designation and role were also recorded.

In the improved supplier evaluation system, we will introduce the hierarchies that help us get deep knowledge about criteria: we synthesize the actual criteria into its integral parts. The purpose of an AHP model is to derive relative scales using judgment from standard scale. The results of the questionnaire are captured in 8 × 8 matrix in a format shown in Fig. 1. While comparing between two criteria, if the left-hand side (LHS) criteria is favored more than the right-hand side (RHS) criteria, the values are to be entered in the respective place in the matrix. On contrary, if the RHS criteria favored more than LHS criteria, the values are to be entered as reciprocal. Since the number of criteria to be compared are more, the number of judgments to be made by the decision-maker are higher (28 in this case). This may lead to the overload of questions leading to inefficiency in the model. Hence, a consistency check is mandatory for the pairwise comparison matrix. If the adequate consistency is not received, the elements of the pairwise consistency matrix are adjusted to ensure that it becomes consistent.

While comparing between two criteria, if the LHS criteria is favored more than the RHS criteria, the values are to be entered in the respective place in the matrix. On contrary, if the RHS criteria favored more than LHS criteria, the values are to be entered as reciprocal. Since the number of criteria to be compared are more, the number of judgments to be made by the decision-maker are higher (28 in this case). This may lead to the overload of questions leading to inefficiency in the model. Hence, a consistency check is mandatory for the pairwise comparison matrix. If the adequate consistency is not received, the elements of the pairwise consistency matrix are adjusted to ensure that it becomes consistent.

The results of the respondents are tabulated and converted to matrix as shown in Fig. 2.

The pairwise comparison of all pairs of criteria at individual hierarchical level helps to simplify the problem especially when



	1	2	3	4	5	6	7	8
1	1	2	1/2	5	1/5	1/3	4	5
2	1/2	1	1/5	5	1/3	1/4	5	2
3	2	5	1	3	1/4	1/2	5	7
4	1/5	1/5	1/3	1	1/8	1/5	1/3	4
5	5	3	4	8	1	2	5	7
6	3	4	2	5	1/2	1	4	8
7	1/4	1/5	1/5	3	1/5	1/4	1	4
8	1/5	1/2	1/7	1/4	1/7	1/8	1/4	1

	1	2	3	4	5	6	7	8
1	1	1	1	4	1/4	1/2	3	4
2	1	1	1/4	4	1/2	1/3	4	1
3	1	4	1	2	1/3	1	4	6
4	1/4	1/4	1/2	1	1/7	1/4	1/2	3
5	4	2	3	7	1	1	4	6
6	2	3	1	4	1	1	3	7
7	1/3	1/4	1/4	2	1/4	1/3	1	3
8	1/4	1	1/6	1/3	1/6	1/7	1/3	1

	1	2	3	4	5	6	7	8
1	1	2	1	4	1/3	1	5	8
2	1/2	1	1	3	1	5	3	5
3	1	1	1	6	2	4	7	7
4	1/4	1/3	1/6	1	1/5	1/4	1/2	3
5	3	1	1/2	5	1	2	5	7
6	1	1/5	1/4	4	1/2	1	5	7
7	1/5	1/3	1/7	2	1/5	1/5	1	3
8	1/8	1/5	1/7	1/3	1/7	1/7	1/3	1

	1	2	3	4	5	6	7	8
1	1	4	2	5	1/6	1	4	7
2	1/4	1	1/5	5	1/3	1/4	1	2
3	1/2	5	1	3	1/4	1/2	5	7
4	1/5	1/5	1/3	1	1/8	1/5	1/3	4
5	6	3	4	8	1	2	5	7
6	1	4	2	5	1/2	1	4	8
7	1/4	1	1/5	3	1/5	1/4	1	4
8	1/7	1/2	1/7	1/4	1/7	1/8	1/4	1

Fig. 2. Preferences of management team.

the decision support system is unclear or has no idea about their importance, and hence AHP paves way to learn from respondents' data. Each respondent examines all paired comparison of criteria, two at a time, and their preference is collected in the form of a matrix R, $R = \begin{bmatrix} r_{11} & \cdots & r_{18} \\ \vdots & \ddots & \vdots \\ r_{81} & \cdots & r_{88} \end{bmatrix}$, where each element r_{ij} represents priority of the decision-maker for *i* over *j*. The matrix is normalized represented as $\bar{R}$ further before eigenvector is calculated to arrive at the criteria weightage and consistency to be ensured less than 10%. By analyzing these consistent matrices, we obtain the weights of the criteria and relative priorities of alternatives. The weight of each criterion is obtained by finding the principle eigenvectors of the comparison matrix. The maximal eigen vector of the comparison matrix is then normalized to obtain the weight vector for criteria.

Vice President of sourcing, the apex person of the sourcing function judges that costing, delivery, and quality are highly preferred, which is evident from the cumulative contribution of 70% of the total weightage. Head of development (GM—sourcing—development) judgments were analyzed and the results were aligned toward quality control, costing, design, and manufacturing capabilities (60%) followed by costing and delivery performance. Quality at any point of development is essential as the development milestones should not be affected by the quality issues during prototype stage or pilot production. Development Head is more concerned about cost in the preliminary stages of the project and expects supplier to demonstrate design and manufacturing capabilities. Quality cost and delivery are predominant for GM souring procurement (60%) followed by other factors like manufacturing and design capabilities. Since the Head of procurement handles various types of commodities like steel, nonmetallic, forgings, proprietary, and costing is of foremost importance. The intention to reduce lead time is also evident, i.e., to avoid imports and plan for long lead parts. The other criteria like TQM, Financial Status, and Management Culture have lesser weightage. DGM sourcing—procurement heading casting domain allots more weightage to costing, delivery, manufacturing capability, and quality control (around 75%). Domain Heads have key metrics of performance measurement mainly in terms of cost reduction (%) and OTIF (%) (on time in full), which is backed up by strong manufacturing capabilities and resolving quality issues. The preferences of management team are presented in Fig. 2. Also, responses of other four managers are obtained in this article.

The eight matrices formed from the responses of the eight respondents are normalized and a priority weight for each supplier evaluation criteria is determined. Weight of criteria *i* is calculated as

$$w_i = \frac{\sum_{j=1}^{8} \bar{r}_{ij}}{8} \; \forall i = 1, \ldots 8. \tag{3}$$

We get $\sum_{j=1}^{8} w_i = 1$ and this process is repeated for all normalized matrices until the weights of each evaluation criteria are calculated. Next step is to check the consistency of each pairwise comparison matrix and avoid inconsistent responses if any. Three factors such as, consistency Index (CI), random consistency index (RCI), and consistency ratio (CR) are calculated according to [57]

$$\mathrm{CI} = \frac{\lambda_{\max} - 8}{8} \tag{4}$$

where $\lambda_{\max}$ is a maximum value

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RCI}} \tag{5}$$

where RCI = 1.4 obtained from Saaty scale. If computed CR ≤ 0.2, the degree of inconsistency is tolerable [58], [59]. Otherwise, the ratings should be adjusted to remove the inconsistency. Once the relative importance of each criteria driving the supplier selection process is determined, we calculate the score for each potential supplier as the sum product of its qualification level for each criterion and the relative importance for the corresponding criteria. This score can be further used to establish rank for each potential supplier.

V. Result

The survey data are analyzed in RStudio platform using "ahpsurvey" package. Supplier evaluation criteria are identified and evaluated by a team of eight experts in a famous automaker firm in India to derive their hierarchical structure. Individual preference weights of the criteria are obtained using dominant eigenvalues method [60]. The results are presented in Fig. 3.

The maximum difference of arithmetic aggregation and dominant eigenvalue methods is plotted to show the heterogeneity in the responses. The maximum difference is less than 0.05 when generalized over all the supplier evaluation criteria considered in this article. The mean and standard deviation of individual preferences on supplier evaluation criteria are presented in Table III.

To visualize the consistencies in the data, CI and CR are determined using (4) and (5). The computed CR is found to be 0.097 overall, which shows that the responses are consistent. However, individual priorities and CRs are calculated and presented in Fig. 4.

It could be observed that the average of individual CRs is found to be 0.219, which is exceeding the tolerable limit (0.2),

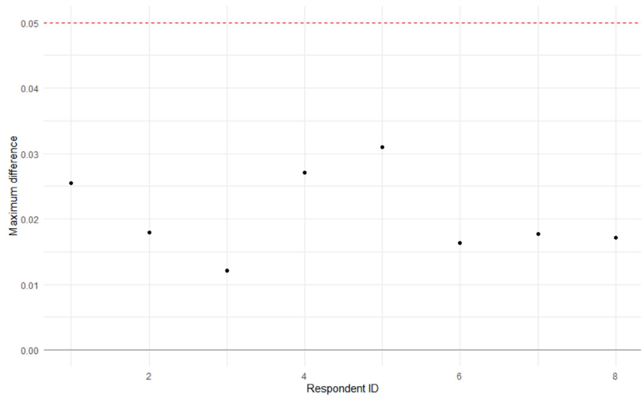


Fig. 3. Eigen value vs. mean aggregation from the responses of eight experts.

TABLE III
DESCRIPTIVE STATISTICS OF AGGREGATED JUDGMENTS

Identifier	Mean	SD
MC	0.045	0.024
DD	0.053	0.015
QC	0.061	0.014
TQM	0.105	0.024
OBC	0.124	0.034
DP	0.118	0.017
FP	0.22	0.046
MCL	0.274	0.076

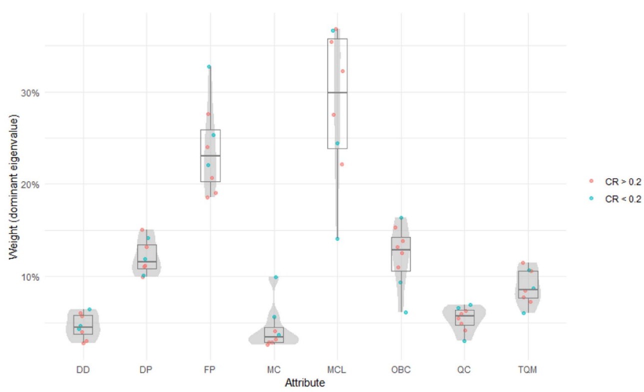


Fig. 4. Priorities of criteria.

and hence respondents should be either asked to adjust their priorities or the inconsistent responses should be adjusted based on Harker's method [61]. To increase the reliability of the priority scales established for each criterion with the pairwise comparison made by few respondents, the consistency of responses using CI and CR are evaluated to elucidate the stability of criteria in affecting the suppliers' performance. However, in the presence of incomplete responses, consistency reduces and

TABLE IV
CONSISTENCY RATIO OF INDIVIDUAL RESPONSES

Decision-maker	Role	Consistency
1	Vice President, Sourcing	9%
2	General Manager, Sourcing Development	9%
3	General Manager, Sourcing Procurement	7%
4	Deputy General manager, Sourcing Procurement	10%
5	Manager 1	8%
6	Manager 2	10%
7	Manager 3	9%
8	Manager 4	10%

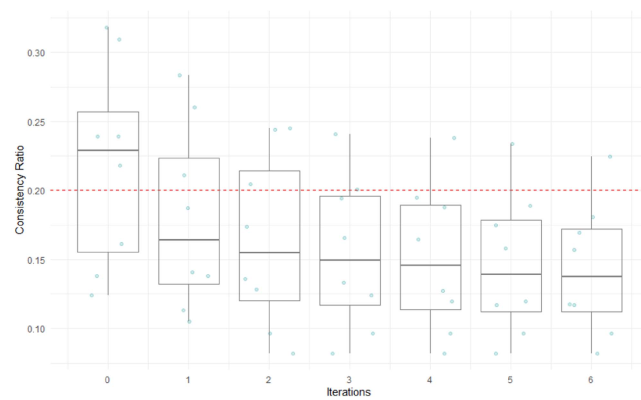


Fig. 5. Consistency ratios at different iterations using Harker's method.

so is the stability of the criteria. We use Harker's method to replace the incomplete and inconsistent responses with derivatives of weights obtained from a known complete response.

In order to determine the source of inconsistencies, first, the pairwise matrix generated for each response is compared with the Saaty's pairwise matrix that has CR $= 0$ to obtain the consistency error. Based on the analysis, the top three inconsistent pairwise comparisons are obtained. It shows the degree of randomness in the decision-makers' responses, and now we can ask the respondents to revise their preferences, or it can be adjusted using Harker's method. The consistency of individual pairwise matrix is obtained as shown in Table IV.

We used the individual consistencies of the responses and the topmost inconsistent pairwise comparisons to adjust the preferences iteratively. After 10 iterations of adjusting the inconsistent responses, we could obtain CR within the tolerable limit (0.2). It is shown in Fig. 5.

The revised weights for the supplier evaluation criteria are obtained and presented in Table V.

Based on the weights of the supplier selection criteria (refer Table V) and the qualification level of supplier with respect to each criterion, the revised score for the supplier is determined based on the weighted sum approach and the value turns out to be 84.1%. Similarly, we can determine the revised score for

TABLE V
WEIGHTS OF SUPPLIER SELECTION CRITERIA

Identifier	Weights
MC	10.80%
DD	8.80%
QC	16.70%
TQM	3.50%
OBC	31.90%
DP	21.30%
FP	4.80%
MCL	2.30%

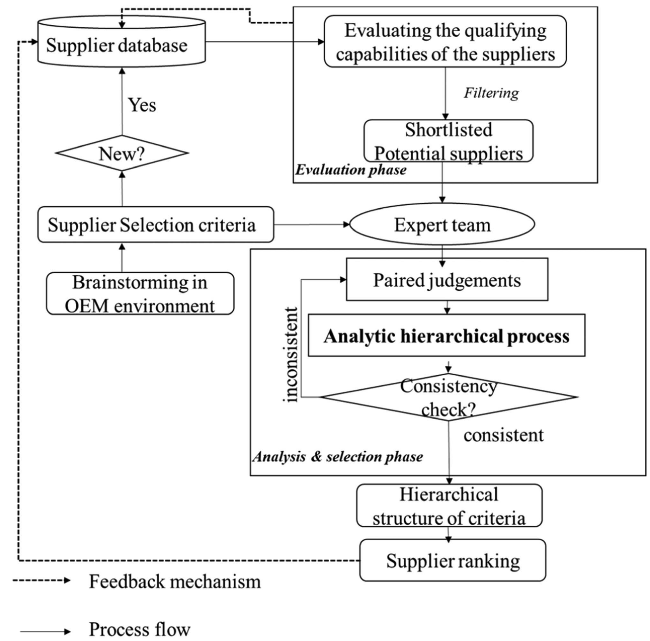


Fig. 6. Proposed framework.

each potential supplier identified by the OEM. This score has to be fed back to the knowledge sharing platform for the benefit of all OEMs. Based on these scores, we can establish the ranks the suppliers and prioritize them, which leads to a reliable and robust supplier selection decision.

VI. Discussion of Findings

The objective of this article is to develop a framework for structured decision-making model for supplier evaluation and selection that considers simultaneously multiple dimensions beyond cost, quality, and delivery. By doing so, the article aims to help OEMs better allocate resources, mitigate risks, and make more informed decisions in supplier selection. There is a need for having a knowledge sharing platform that evolves and updates the supplier database as per the experiences of OEMs, researchers, and academicians. The set of supplier selection and evaluation criteria currently in use in an OEM environment is to be identified, which often changes based on their customer experience about the end products, the inputs from their manufacturing team, and their strategic priorities. The knowledge sharing platform takes feedback from the OEM environment about the criteria currently in use. Then, it receives collective feedback from various OEMs after evaluating the existing and new suppliers based on their past performance against certain qualifiers. This platform further guides an OEM in the process of supplier selection and evaluation. The proposed framework is presented in Fig. 6.

This framework opens different perspectives aiming toward better resource allocation, risk mitigation and saving cost, and time and money. The improved supplier evaluation mechanism includes key capabilities and multiple dimensions, which include manufacturing, design, development, problem-solving, financial status, management culture, strategic fit, technology adoption, IT, and communication infrastructure. Identifying and analyzing evaluation criteria is crucial for OEMs to stay competitive and respond to changing market conditions. The findings developed a structured decision-making model of supplier evaluation by assigning weightage to various selection criteria compared to the conventional method of evaluating supplier predominantly based on cost, quality, and delivery. The MCDM model reduced the complexity of decision-making by systematizing the decision-makers opinions, decisions, and emotions into a structured environment and assessing the relative significance of criteria. Though the metrics set are not too exhaustive to meet the continuously evolving business model, this project sets as the foundation for evaluating decision-making, which involves multiple criteria. This MCDM model can be used by the OEM for project prioritization, make or buy decision. Furthermore, the improved supplier evaluation mechanism also enables companies to identify and mitigate risks associated with supplier selection. This can be achieved by thoroughly evaluating suppliers' financial status, management culture, and strategic fit, which can help to identify potential issues that may arise during the relationship. Additionally, assessing suppliers' technology adoption and IT and communication infrastructure can help companies identify suppliers that are well-positioned to support their digitalization efforts.

Moreover, this improved supplier evaluation mechanism also enables companies to identify suppliers that are best suited for specific projects or products. For example, by assessing suppliers' manufacturing, design, and development capabilities, companies can identify suppliers that are well-suited to support their product development efforts. Additionally, by assessing suppliers' problem-solving capabilities, companies can identify suppliers that are well-suited to support their ongoing operations. The improved supplier evaluation mechanism is a valuable tool for companies to identify the best suppliers to support their strategic goals and objectives. By assessing suppliers based on multiple dimensions and key capabilities, companies can make more informed decisions about which suppliers to select, and how to improve relationships with existing suppliers. Additionally, the MCDM model that developed in this article can be used as a foundation for evaluating decision-making that involves multiple criteria, which can help companies to reduce the complexity of decision-making and make more effective supplier selection decisions.

VII. Conclusion

This article highlights the importance of knowledge sharing among industry professionals and academicians in developing a robust and highly relevant decision-making framework for selecting suppliers for Asian automakers. Firms are realizing the necessity of achieving strategic fit in supplier–buyer relations to stay competitive and improve overall supply chain performance. While traditional supplier evaluation models are more focused on cost, quality, and delivery aspects of parts and components, we developed a robust evaluation model incorporating other strategic, financial, and cultural aspects suitable for Asian automaking industry. We first used a scoring mechanism to evaluate the compliances of these criteria among the existing potential suppliers identified by an Asian OEM, and we found variation in compliances and hence we recognized the need for prioritizing the criteria using an MCDM method, such as AHP. We prioritized the criteria and found that the financial transparency through open-book costing is a highly sought-after criteria followed by quality, delivery, and manufacturing capabilities of the suppliers.

A. Theoretical Implications

This article has important theoretical implication. Cost-based supplier evaluation framework is developed by researchers and widely accepted in automobile industries [6]. AHP is used to widely evaluate suppliers based on their track records and often with respect to few criteria predominantly based on cost and quality and delivery performance [9]. The need for configurable supplier evaluation and selection criteria is emphasized by researchers [49], [62]. We have identified a list of supplier evaluation criteria suitable for Asian automakers from the experts in the field that include manufacturing capability, design and development capability, problem-solving capability, quality control capability, financial performance, accounting capability, management culture including strategic fit, technology adoption, and IT and communication infrastructure. The identified supplier capabilities serve to develop a robust decision-making framework for Asian automakers.

B. Managerial Implications

The results of the article highlight key managerial implications. While quality, cost, and delivery performance were traditionally used for supplier evaluation and selection, other vital capabilities of this decision-making process are established in this article. It is noteworthy that open-book costing, delivery track record, and quality control rank high in importance for supplier evaluation followed by manufacturing capability exhibited by the suppliers. Open-book costing plays a major role in establishing strong buyer–supplier relationships [63]. The open-book costing principles enable sharing of risks and rewards among the supplier and the buyer allowing better risk management. The exchange of cost information between the buyer and supplier helps interorganizational cost management and bring strategic coordination. It helps identifying the interorganizational surplus zone in the cost-benefit curve and enables better supply-demand coordination. Sharing sensitive organization information among the collaborating parties improves mutual trust, avoids information asymmetry, and simplifies price negotiations. However, bringing balance of power between supplier and buyer, bidirectional open book costing, win–win price negotiations are real challenges in open-book costing. It is a recent procurement model widely being adopted for its transparency and better partnering benefits, however lacks discussion. Delivery performance followed by quality control that were incorporated in many traditional decision-making frameworks have been similarly prioritized in this article. Manufacturing capability is a default criterion to identify potential suppliers in any industry. These four criteria share more than 80% (refer Table V) of importance among the eight key capabilities identified in this article, which serve as a reference mechanism for Asian automakers while making supplier selection decisions.

C. Limitations of the Study and Future Research Directions

This article demonstrates developing a supplier selection framework for Asian automakers using collaborative learning and knowledge sharing among industry practitioners and academic researchers. First, identification of supplier evaluation criteria is carried out based on the practitioners' perspectives and they are evaluated for the existing supplier database available in an Asian OEM. However, relevant and industry-specific supplier evaluation criteria must be identified to develop supplier evaluation framework for other industries. In this article, we have only evaluated main criteria for making supplier selection decisions and we have found that four of these criteria, such as open-book costing, quality, delivery performance, and manufacturing capability, have been perceived to play major role (more than 80% as given in Table V) depicting overall performance of the supplier. Further, the digital ecosystem is proposed to enhance the operational capability of the OEM. However, future articles should drill down to more subcriteria to evaluate the main criteria. Future researchers should focus identifying subcriteria related to these four main criteria that are suitable for an automaking industry.

References

[1] M. Wilhelm, C. Blome, E. Wieck, and C. Y. Xiao, "Implementing sustainability in multi-tier supply chains: Strategies and contingencies in managing sub-suppliers," *Int. J. Prod. Econ.*, vol. 182, pp. 196–212, 2016, doi: 10.1016/j.ijpe.2016.08.006.

[2] M. Taheri-Bavil-Oliaei, S. H. Zegordi, and R. Tavakkoli-Moghaddam, "Bi-objective build-to-order supply chain network design under uncertainty and time-dependent demand: An automobile case study," *Comput. Ind. Eng.*, vol. 154, 2021, Art. no. 107126, doi: 10.1016/j.cie.2021.107126.

[3] N. Kim, Y. Park, and D. Lee, "Differences in consumer intention to use on-demand automobile-related services in accordance with the degree of face-to-face interactions," *Technol. Forecasting Social Change*, vol. 139, pp. 277–286, 2019, doi: 10.1016/j.techfore.2018.11.014.

[4] "The future of work in the automotive industry: The need to invest in people's capabilities and decent and sustainable work," Griffin and Mary, May 2020. [Online]. Available: www.ilo.org/publns

[5] S. S. Bhullar, V. K. Nangia, and A. Batish, "The impact of academia-industry collaboration on core academic activities: Assessing the latent dimensions," *Technol. Forecasting Social Change*, vol. 145, pp. 1–11, 2019, doi: 10.1016/j.techfore.2019.04.021.

[6] F. Zhou, X. Wang, M. Goh, L. Zhou, and Y. He, "Supplier portfolio of key outsourcing parts selection using a two-stage decision making framework for Chinese domestic auto-maker," *Comput. Ind. Eng.*, vol. 128, pp. 559–575, 2019, doi: 10.1016/j.cie.2018.12.014.

[7] R. Drauz, "Re-insourcing as a manufacturing-strategic option during a crisis—Cases from the automobile industry," *J. Bus. Res.*, vol. 67, no. 3, pp. 346–353, 2014, doi: 10.1016/j.jbusres.2013.01.004.

[8] F. Veloso and S. Fixson, "Make–buy decisions in the auto industry," *Technol. Forecasting Social Change*, vol. 67, no. 2/3, pp. 239–257, 2001, doi: 10.1016/s0040-1625(00)00092-5.

[9] V. F. Yu, M. Qiu, and J. N. D. Gupta, "Improving supplier capability through training: Evidence from the Chinese automobile industry," *Comput. Ind. Eng.*, vol. 163, 2022, Art. no. 107825, doi: 10.1016/j.cie.2021.107825.

[10] K. Mathiyazhagan, V. Agarwal, A. Appolloni, T. Saikouk, and A. Gnanavelbabu, "Integrating lean and agile practices for achieving global sustainability goals in Indian manufacturing industries," *Technol. Forecasting Social Change*, vol. 171, 2021, Art. no. 120982, doi: 10.1016/j.techfore.2021.120982.

[11] E. K. Lee, S. Ha, and S. K. Kim, "Supplier selection and management system considering relationships in supply chain management," *IEEE Trans. Eng. Manage.*, vol. 48, no. 3, pp. 307–318, Aug. 2001, doi: 10.1109/17.946529.

[12] P. K. Dey, A. Bhattacharya, and W. Ho, "Strategic supplier performance evaluation: A case-based action research of a U.K. manufacturing organisation," *Int. J. Prod. Econ.*, vol. 166, pp. 192–214, 2015, doi: 10.1016/j.ijpe.2014.09.021.

[13] M. Almasi, S. Khoshfetrat, and M. R. Galankashi, "Sustainable supplier selection and order allocation under risk and inflation condition," *IEEE Trans. Eng. Manage.*, vol. 68, no. 3, pp. 823–837, Jun. 2021, doi: 10.1109/TEM.2019.2903176.

[14] Y. Peng, X. Yan, Y. Jiang, M. Ji, and T. C. E. Cheng, "Competition and coordination for supply chain networks with random yields," *Int. J. Prod. Econ.*, vol. 239, 2021, Art. no. 108204, doi: 10.1016/j.ijpe.2021.108204.

[15] F. Kellner, B. Lienland, and S. Utz, "An a posteriori decision support methodology for solving the multi-criteria supplier selection problem," *Eur. J. Oper. Res.*, vol. 272, no. 2, pp. 505–522, 2019, doi: 10.1016/j.ejor.2018.06.044.

[16] S. Thevenin, O. Ben-Ammar, and N. Brahimi, "Robust optimization approaches for purchase planning with supplier selection under lead time uncertainty," *Eur. J. Oper. Res.*, vol. 303, no. 3, pp. 1199–1215, 2022, doi: 10.1016/j.ejor.2022.03.029.

[17] R. F. Saen, "Suppliers selection in the presence of both cardinal and ordinal data," *Eur. J. Oper. Res.*, vol. 183, no. 2, pp. 741–747, 2007, doi: 10.1016/j.ejor.2006.10.022.

[18] J. Nenavani and R. K. Jain, "Examining the impact of strategic supplier partnership, customer relationship and supply chain responsiveness on operational performance: The moderating effect of demand uncertainty," *J. Bus. Ind. Marketing*, vol. 37, no. 5, pp. 995–1011, 2022, doi: 10.1108/JBIM-10-2020-0461.

[19] P. C. Shashi, R. Cerchione, and R. Singh, "The impact of leanness and innovativeness on environmental and financial performance: Insights from Indian SMEs," *Int. J. Prod. Econ.*, vol. 212, pp. 111–124, 2019, doi: 10.1016/j.ijpe.2019.02.011.

[20] L. Z. Tong, J. Wang, and Z. Pu, "Sustainable supplier selection for SMEs based on an extended PROMETHEE II approach," *J. Cleaner Prod.*, vol. 330, 2022, Art. no. 129830, doi: 10.1016/j.jclepro.2021.129830.

[21] S. S. Nudurupati et al., "Transforming sustainability of Indian small and medium-sized enterprises through circular economy adoption," *J. Bus. Res.*, vol. 149, pp. 250–269, 2022, doi: 10.1016/j.jbusres.2022.05.036.

[22] "Small and medium enterprises: India's engines of growth," The World bank, 2010. [Online]. Available: http://www.worldbank.org/en/news/feature/2010/03/10/small-and-medium-enterprises-indias-engines-of-growth

[23] "Annual report 2020–2021," Ministry of MSME, Government of India, Ministry of Micro, Small and Medium Enterprises, 2021, p. 156.

[24] K. Loader and S. Norton, "SME access to public procurement: An analysis of the experiences of SMEs supplying the publicly funded U.K. heritage sector," *J. Purchasing Supply Manage.*, vol. 21, no. 4, pp. 241–250, 2015, doi: 10.1016/j.pursup.2015.02.001.

[25] Y. Kalyuzhnova, D. Azhgaliyeva, and M. Belitski, "Public policy instruments for procurement: An empirical analysis," *Technol. Forecasting Social Change*, vol. 176, 2022, Art. no. 121472, doi: 10.1016/j.techfore.2022.121472.

[26] K. Patil, "Public procurement policy for small and medium enterprises in developing countries: Evidence from India," *Int. J. Public Sector Manage.*, vol. 30, no. 4, pp. 391–410, 2017, doi: 10.1108/IJPSM-10-2016-0160.

[27] M. A. Naqvi and S. H. Amin, "Supplier selection and order allocation: A literature review," *J. Data, Inf. Manage.*, vol. 3, no. 2, pp. 125–139, 2021, doi: 10.1007/s42488-021-00049-z.

[28] C. A. Weber, J. R. Current, and W. C. Benton, "Vendor selection criteria and methods," *Eur. J. Oper. Res.*, vol. 50, no. 1, pp. 2–18, 1991, doi: 10.1016/0377-2217(91)90033-R.

[29] T. Sawik, "Single vs. multiple objective supplier selection in a make to order environment," *Omega*, vol. 38, no. 3/4, pp. 203–212, 2010, doi: 10.1016/j.omega.2009.09.003.

[30] R. Kumar, K. Lamba, and A. Raman, "Role of zero emission vehicles in sustainable transformation of the Indian automobile industry," *Res. Transp. Econ.*, vol. 90, 2021, Art. no. 101064, doi: 10.1016/j.retrec.2021.101064.

[31] H. Hadian, S. Chahardoli, A. M. Golmohammadi, and A. Mostafaeipour, "A practical framework for supplier selection decisions with an application to the automotive sector," *Int. J. Prod. Res.*, vol. 58, no. 10, pp. 2997–3014, 2020, doi: 10.1080/00207543.2019.1624854.

[32] M. Sharma and S. Joshi, "Digital supplier selection reinforcing supply chain quality management systems to enhance firm's performance," *Total Qual. Manage. J.*, vol. 35, no. 1, pp. 102–130, 2023, doi: 10.1108/TQM-07-2020-0160.

[33] H. Taherdoost and M. Madanchian, "Multi-criteria decision making (MCDM) methods and concepts," *Encyclopedia*, vol. 3, no. 1, pp. 77–87, 2023, doi: 10.3390/encyclopedia3010006.

[34] F. Dweiri, S. Kumar, S. A. Khan, and V. Jain, "Designing an integrated AHP based decision support system for supplier selection in automotive industry," *Expert Syst. Appl.*, vol. 62, pp. 273–283, 2016, doi: 10.1016/j.eswa.2016.06.030.

[35] V. S. Lai, B. K. Wong, and W. Cheung, "Group decision making in a multiple criteria environment: A case using the AHP in software selection," *Eur. J. Oper. Res.*, vol. 137, no. 1, pp. 134–144, 2002, doi: 10.1016/S0377-2217(01)00084-4.

[36] W. Ho, X. Xu, and P. K. Dey, "Multi-criteria decision making approaches for supplier evaluation and selection: A literature review," *Eur. J. Oper. Res.*, vol. 202, no. 1, pp. 16–24, 2010, doi: 10.1016/j.ejor.2009.05.009.

[37] L. C. Leung and D. Cao, "On the efficacy of modeling multi-attribute decision problems using AHP and Sinarchy," *Eur. J. Oper. Res.*, vol. 132, no. 1, pp. 39–49, 2001, doi: 10.1016/S0377-2217(00)00111-9.

[38] R. Whitaker, "Criticisms of the analytic hierarchy process: Why they often make no sense," *Math. Comput. Model.*, vol. 46, no. 7/8, pp. 948–961, 2007, doi: 10.1016/j.mcm.2007.03.016.

[39] S. Y. Chou and Y. H. Chang, "A decision support system for supplier selection based on a strategy-aligned fuzzy SMART approach," *Expert Syst. Appl.*, vol. 34, no. 4, pp. 2241–2253, 2008, doi: 10.1016/j.eswa.2007.03.001.

[40] L. Zhang, X. Pu, Z. Cai, H. Liu, and L. Liang, "Uniting partners to cope with environmental uncertainty: Disentangling the role of social capital in developing supply chain agility," *J. Purchasing Supply Manage.*, to be published, doi: 10.1016/j.pursup.2023.100822.

[41] M. C. Schmidt, J. W. Veile, J. M. Müller, and K. I. Voigt, "Industry 4.0 implementation in the supply chain: A review on the evolution of buyer-supplier relationships," *Int. J. Prod. Res.*, to be published, doi: 10.1080/00207543.2022.2120923.

[42] M. A. Alabdali and M. A. Salam, "The impact of digital transformation on supply chain procurement for creating competitive advantage: An empirical study," *Sustainability*, vol. 14, no. 19, 2022, Art. no. 12269, doi: 10.3390/su141912269.

[43] K. P. Liu, W. Chiu, J. Chu, and L. J. Zheng, "The impact of digitalization on supply chain integration and performance," *J. Glob. Inf. Manage.*, vol. 30, no. 1, pp. 1–20, 2022, doi: 10.4018/jgim.311450.

[44] R. Angkiriwang, I. N. Pujawan, and B. Santosa, "Managing uncertainty through supply chain flexibility: Reactive vs. proactive approaches," *Prod. Manuf. Res.*, vol. 2, no. 1, pp. 50–70, 2014, doi: 10.1080/21693277.2014.882804.

[45] M. Sagar and D. Singh, "Supplier selection criteria: Study of automobile sector in India," *Int. J. Eng. Res. Develop.*, vol. 4, no. 4, pp. 34–39, 2012.

[46] R. Handfield, S. V. Walton, R. Sroufe, and S. A. Melnyk, "Applying environmental criteria to supplier assessment: A study in the application of the analytical hierarchy process," *Eur. J. Oper. Res.*, vol. 141, no. 1, pp. 70–87, 2002, doi: 10.1016/S0377-2217(01)00261-2.

[47] Y. Beikkhakhian, M. Javanmardi, M. Karbasian, and B. Khayambashi, "The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods," *Expert Syst. Appl.*, vol. 42, no. 15/16, pp. 6224–6236, 2015, doi: 10.1016/j.eswa.2015.02.035.

[48] J. Gu, X. Shi, P. Wang, and X. Xu, “Examining the impact of upstream and downstream relationship stability and concentration on firms’ financial performance,” *J. Bus. Res.*, vol. 141, pp. 229–242, 2022, doi: 10.1016/j.jbusres.2021.12.018.

[49] B. Ageron, A. Gunasekaran, and A. Spalanzani, “IS/IT as supplier selection criterion for upstream value chain,” *Ind. Manage. Data Syst.*, vol. 113, no. 3, pp. 443–460, 2013, doi: 10.1108/02635571311312703.

[50] B. Cao and J. Gao, “Quality contracts with the supplier’s private product manufacturability information,” *Comput. Ind. Eng.*, vol. 125, pp. 309–318, 2018, doi: 10.1016/j.cie.2018.08.033.

[51] F. Skarp and L. E. Gadde, “Problem solving in the upgrading of product offerings—A case study from the steel industry,” *Ind. Marketing Manage.*, vol. 37, no. 6, pp. 725–737, 2008, doi: 10.1016/j.indmarman.2007.09.002.

[52] O. Bayazit and B. Karpak, “An analytical network process-based framework for successful total quality management (TQM): An assessment of Turkish manufacturing industry readiness,” *Int. J. Prod. Econ.*, vol. 105, no. 1, pp. 79–96, 2007, doi: 10.1016/j.ijpe.2005.12.009.

[53] G. Merckx and A. Chaturvedi, “Short vs. long-term procurement contracts when supplier can invest in cost reduction,” *Int. J. Prod. Econ.*, vol. 227, 2020, Art. no. 107652, doi: 10.1016/j.ijpe.2020.107652.

[54] T. Ngniatedema, L. A. Fono, and G. D. Mbondo, “A delayed product customization cost model with supplier delivery performance,” *Eur. J. Oper. Res.*, vol. 243, no. 1, pp. 109–119, 2015, doi: 10.1016/j.ejor.2014.11.017.

[55] G. J. L. Micheli, E. Cagno, and A. Di Giulio, “Reducing the total cost of supply through risk-efficiency-based supplier selection in the EPC industry,” *J. Purchasing Supply Manage.*, vol. 15, no. 3, pp. 166–177, 2009, doi: 10.1016/j.pursup.2009.05.001.

[56] G. H. Tzeng and J. J. Huang, *Multiple Attribute Decision Making: Methods and Applications*. Boca Raton, FL, USA: CRC Press, 2011.

[57] T. L. Saaty, “How to make a decision: The analytic hierarchy process,” *Eur. J. Oper. Res.*, vol. 48, no. 1, pp. 9–26, 1990, doi: 10.1016/0377-2217(90)90057-I.

[58] T. L. Saaty and K. P. Kearns, “The analytic hierarchy process,” *Anal. Plan.*, pp. 19–62, 1985, doi: 10.1016/b978-0-08-032599-6.50008-8.

[59] T. Saaty, “A scaling method for priorities in hierarchical structures,” *J. Math. Psychol.*, vol. 15, pp. 59–62, 1977.

[60] T. L. Saaty, “Decision-making with the AHP: Why is the principal eigenvector necessary,” *Eur. J. Oper. Res.*, vol. 145, no. 1, pp. 85–91, 2003, doi: 10.1016/S0377-2217(02)00227-8.

[61] P. T. Harker, “Incomplete pairwise comparisons in the analytic hierarchy process,” *Math. Model.*, vol. 9, no. 11, pp. 837–848, 1987, doi: 10.1016/0270-0255(87)90503-3.

[62] S. H. Huang and H. Keskar, “Comprehensive and configurable metrics for supplier selection,” *Int. J. Prod. Econ.*, vol. 105, no. 2, pp. 510–523, 2007, doi: 10.1016/j.ijpe.2006.04.020.

[63] P. Romano and M. Formentini, “Designing and implementing open book accounting in buyersupplier dyads: A framework for supplier selection and motivation,” *Int. J. Prod. Econ.*, vol. 137, no. 1, pp. 68–83, 2012, doi: 10.1016/j.ijpe.2012.01.013.