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A Literature Review on Sustainable Supplier Selection in the Automotive Industry 5.0 Era

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ABSTRACT

The transition towards Industry 5.0 is expanding supplier selection beyond conventional cost, quality, and delivery measures to include sustainability, resilience, digital capability, and human centered considerations. This study systematically reviews research on sustainable supplier selection in the automotive and related industries published between 2000 and April 2025. The review examines the sustainability criteria used, the decision-making methods applied, and the extent to which Industry 5.0 enablers have been incorporated into supplier evaluation. A total of 121 peer reviewed studies were identified from Scopus, Web of Science, ScienceDirect, IEEE Xplore, and SpringerLink and screened using the PRISMA 2020 framework. The findings show that environmental and economic criteria dominate the literature, appearing in 96% and 93% of the studies respectively. Social criteria were reported in 41% of studies, while Technological/Industry 5.0 Readiness appeared in 27%. Classical MCDM methods accounted for 42% of the studies, followed by fuzzy methods at 31% and hybrid approaches at 27%. Among the Industry 5.0 enablers, circular economy and regenerative manufacturing had the highest representation, followed by digital resilience and human machine collaboration. Overall, the review indicates that sustainable supplier selection is becoming more sophisticated, but the integration of social and Industry 5.0 considerations remains uneven. The findings highlight the need for more integrated and adaptive approaches that can address sustainability, uncertainty, resilience, technological capability, and changing supplier conditions within the automotive Industry 5.0 environment.

1.0 INTRODUCTION

1.1 Background

Sustainability in supply chain management has evolved considerably over the 21st century, moving well beyond simple regulatory compliance to become a genuine source of strategic competitiveness. Companies now rely on it to generate value and remain resilient in international markets. Supplier selection reflects this shift clearly: it affects not only cost efficiency, product quality, and delivery reliability, but

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increasingly the environmental and social performance of the entire supply chain (Govindan *et al.*, 2015; Awasthi & Kannan, 2023).

This is especially true in the automotive industry, where highly developed, globalized production chains create strong dependency on component suppliers, raising the stakes of sustainable sourcing. At the same time, consumers and regulators are placing increasing pressure on automakers to ensure products are not just high quality, but sustainably and ethically sourced. This is where Industry 5.0 becomes relevant. Unlike Industry 4.0, which centered on automation and digitalization, Industry 5.0 represents a more human-centered, sustainable, and resilient approach to manufacturing. Supplier selection must evolve accordingly, moving beyond short-term economic figures to a fuller assessment grounded in the Triple Bottom Line (TBL) of environmental, social, and economic sustainability.

The TBL framework, introduced by Elkington (1997), has increasingly shaped sustainable supply chain research. Where earlier evaluation methods focused mainly on cost and quality, the TBL model introduces three interdependent dimensions of performance: environmental, economic, and social. This broader lens aligns supplier evaluation with the human-centered, sustainability-driven priorities that define Industry 5.0.

Each dimension captures a distinct aspect of supplier performance. The environmental dimension focuses on reducing environmental impact through practices such as lowering harmful emissions, improving energy and resource efficiency, and implementing effective waste-disposal programmes. The economic dimension retains the traditional supplier benchmarks of cost, product value, and reliability, but places greater emphasis on long-term value creation and resilience rather than short-term financial performance alone. The social dimension addresses labour welfare, occupational health and safety, community development, and ethical business practices. It reflects the expectation that supply chains should create not only economic value but also broader social benefits (Elkington, 1997; Brandenburg *et al.*, 2014).

This framework is especially relevant to the automotive industry, which faces mounting pressure to decarbonize production, improve cost-effectiveness, and demonstrate responsible, ethical practices across globally distributed supply chains. To manage this complexity, researchers and practitioners are increasingly turning to hybrid Multi-Criteria Decision-Making (MCDM) models. These models offer structured ways to navigate trade-offs between competing supplier criteria, such as cost against carbon footprint, or delivery time against labor ethics, by combining the strengths of different decision-making techniques. Fuzzy logic, for instance, can handle uncertainty in expert judgment, AHP (Analytic Hierarchy Process) can determine which sustainability criteria matter most, and TOPSIS or VIKOR can rank suppliers accordingly. In this way, the TBL framework defines what should be evaluated, while hybrid MCDM defines how. Together, they align supplier selection with the broader objectives of Industry 5.0.

1.2 The Automotive Industry in the Industry 5.0 Era

The automotive industry has always been at the forefront of innovative manufacturing, from Henry Ford's assembly line to today's Industry 4.0 technologies, including IoT-powered equipment, digital twins, and predictive maintenance (Kamble *et al.*, 2022). Industry 4.0 brought clear gains in automation, efficiency, and data-driven decision-making. However, it has also been criticized for placing too little emphasis on human-centered and resilience-oriented values (Nahavandi, 2019).

Industry 5.0, proposed by the European Commission in 2021, addresses these limitations. It establishes human-machine partnership, sustainability, and resilience as core standards for industry going forward (Breque *et al.*, 2021). Three ideas sit at the center of this shift. First, human-machine symbiosis, seen in collaborative robots (cobots) and AI designed to enhance human skills rather than replace them (Javaid *et al.*, 2022). Second, sustainable production built around circular economy principles, closed-loop supply chains, and eco-innovation (Dwivedi *et al.*, 2022). Third, resilient supply networks that can adapt to disruption through digital twins, blockchain-enabled traceability, and distributed decision-making (Bag *et al.*, 2022).

For the automotive industry, Industry 5.0 marks the beginning of a new era defined by human-centered, environmentally regenerative, and digitally resilient supply chains. In this context, supplier selection can no longer rest on price alone. It must instead reflect alignment with the values Industry 5.0 represents

1.3 Status of the Research and Identified Gaps

Research on sustainable supplier selection within the automotive industry has grown steadily over the past two decades. Numerous studies apply multi-criteria decision-making (MCDM) methods, including AHP, TOPSIS, VIKOR, and their fuzzy and hybrid extensions, to assess supplier sustainability (Kaur & Singh, 2021; Mohammed *et al.*, 2019). More recently, hybrid models that combine multiple MCDM techniques, or pair them with artificial intelligence methods such as ANN and genetic algorithms, have become increasingly common. These approaches help manage uncertainty, refine criteria weighting, and improve the optimization of decision outcomes (Ghorabaee *et al.*, 2017; Liang *et al.*, 2022).

Despite this progress, three key gaps remain evident in the literature.

1. Limited Industry 5.0 Integration. Most existing models are still grounded in Industry 4.0 thinking. They largely overlook human-centricity and resilience as meaningful supplier assessment criteria.

2. Underrepresentation of Social Sustainability. Environmental and economic standards are well covered in the literature. Worker well-being, inclusion, and ethical practice, by contrast, remain significantly underexplored.

3. Limited Real-World Validation. Most proposed models remain confined to conceptual or simulated settings. Few have been tested on actual automotive supply chains to confirm their practical soundness and applicability.

It is worth situating these gaps against existing reviews explicitly. This review is not the first to examine sustainable supplier selection or Industry 5.0 individually: Kaur and Singh (2021) reviewed sustainable supplier selection but did so within an Industry 4.0 frame, without addressing human-centricity or resilience as selection criteria in their own right, while Awasthi and Kannan (2023) focused specifically on green supplier development programmes rather than the broader Industry 5.0 enabler set. More recent reviews of Industry 5.0 supply chains, such as Dacre *et al.* (2024), address the Industry 5.0 paradigm at the level of supply-chain design generally rather than the specific decision of which supplier to select. The present review focuses on the intersection of three elements, namely sustainability criteria, MCDM methodologies, and Industry 5.0 enablers within automotive supplier selection. It also uses quantitative coding to assess the extent to which these elements have been adopted in the literature. This approach goes beyond treating Industry 5.0 as a purely conceptual lens.

This paper aims at carrying out a literature review on sustainable supplier selection in the automotive industry in the explicit Industry 5.0 context.

The specific objectives of this study are to:

1. Determine and categorize sustainability requirements applied in the automotive supplier selection process with a focus on Industry 5.0 enablers.

2. Characterize and compare classical, fuzzy, and hybrid methods of decision-making used in the literature.

3. Evaluate the degree to which the concept of Industry 5.0 (human-machine collaboration, digital resilience, and circular economy) is reflected in existing models.

2.0 LITERATURE REVIEW

Supplier selection has historically played an important role in the automotive industry, particularly with the expansion of globalized manufacturing in the late twentieth century. Early supplier evaluation focused mainly on the traditional procurement priorities of cost, quality, and delivery (Ho *et al.*, 2010). Over time, environmental and social performance were added as sustainability concerns and regulatory requirements became more prominent (Awasthi & Kannan, 2023). This shift reflects a broader change in supply chain management, where sustainability has moved beyond a regulatory requirement and become an important element of strategic competitiveness.

From the early 2000s, researchers began applying multi-criteria decision-making (MCDM) techniques to incorporate sustainability into supplier selection. The automotive industry was among the important application areas because of its complex multi-tier supply chains and stringent Original Equipment Manufacturer

(OEM) requirements (Amindoust *et al.*, 2012; Kannan *et al.*, 2014). The field has since developed to include hybrid approaches that combine two or more MCDM techniques, as well as methods that integrate MCDM with optimisation and artificial intelligence. These developments have helped decision-makers handle larger amounts of information and address uncertainty in supplier evaluation (Ghorabaee *et al.*, 2017; Liang *et al.*, 2022).

The conceptual foundation of sustainable supplier selection is closely related to the Triple Bottom Line (TBL) model, which emphasises a balance between economic, environmental, and social performance (Elkington, 1997). In the automotive context, environmental considerations include carbon emissions, energy and resource efficiency, waste reduction, hazardous substance management, and eco-design practices (Govindan *et al.*, 2015; Brandenburg *et al.*, 2014). These considerations have also influenced supplier requirements, with many automotive manufacturers placing greater emphasis on environmental management standards and circular economy practices (Dwivedi *et al.*, 2022).

The economic dimension remains central to supplier evaluation, with emphasis on cost competitiveness, quality, reliability, and innovation capability (Kaur & Singh, 2021; Mohammed *et al.*, 2019). Social factors are equally relevant and include worker safety, labour rights, diversity, and community development (Yawar & Seuring, 2017). Assessing these factors, however, can be difficult, particularly among lower-tier suppliers across global supply chains. Unlike cost and some environmental indicators, social performance is often difficult to verify at scale. Studies that include social criteria therefore tend to rely on single-tier or self-reported measures rather than multi-tier verification. The limited representation of social criteria in the literature may consequently reflect measurement challenges rather than a lower level of importance.

Technological capability has also gained attention as supplier evaluation has evolved. Recent studies have introduced a fifth dimension, referred to in this review as Technological/Industry 5.0 Readiness. The dimension captures a supplier's ability to integrate automation, artificial intelligence, digitalization, and human-machine collaboration into its operations (Javaid *et al.*, 2022). Different terms have been used for related concepts in the literature, including technological preparedness and digital resilience. For consistency, this review uses Technological/Industry 5.0 Readiness as the broader term.

The growing range of supplier-selection criteria has increased the use of multi-criteria decision-making (MCDM) techniques. Methods such as AHP (Saaty, 1980), TOPSIS (Hwang & Yoon, 1981), VIKOR (Opricovic & Tzeng, 2004), and ANP (Saaty, 1996) have been widely applied to weight criteria and rank suppliers. Their application becomes more challenging, however, when expert assessments involve linguistic uncertainty and subjective judgement. Fuzzy extensions have consequently been developed to address this limitation. For instance, Fuzzy AHP-TOPSIS has been applied to automotive supplier selection to

handle imprecision in expert evaluations (Chen *et al.*, 2006; Kannan *et al.*, 2014).

The literature has subsequently moved towards hybrid MCDM approaches. Some studies combine two or more MCDM techniques, while others integrate MCDM with optimization or artificial intelligence. Rezaei (2015), for example, combined BWM with DEA for efficiency-based supplier selection. Liang *et al.* (2022) used Fuzzy DEMATEL and ANP to establish causal relationships among sustainability criteria before ranking suppliers. Such developments have expanded the capacity of MCDM to address complex supplier-selection problems.

Despite these advances, the choice of methods within hybrid models is not always clearly justified. Researchers often adopt a particular combination based on previous applications or methodological precedent. Less attention is given to whether the selected techniques are the most appropriate for the specific characteristics of the decision problem. As a result, limited evidence exists on how factors such as uncertainty, criterion interdependence, and ranking requirements should guide the selection of an appropriate MCDM combination.

Industry 5.0 introduces another layer of complexity to sustainable supplier selection. Its emphasis differs from the efficiency-driven focus associated with Industry 4.0. Greater attention is now given to human-centeredness, resilience, and sustainability**,** alongside technological advancement. Supplier evaluation must therefore consider capabilities such as human-machine collaboration, digital resilience, cybersecurity, adaptive manufacturing, and circularity. Examples include collaborative robots, human-AI decision support, remanufacturing, recycling, and regenerative production systems. Although these issues have received some attention, the integration of human-centeredness, resilience, and sustainability within supplier evaluation remains limited (Bag *et al.*, 2022).

In many existing studies, Industry 5.0 capabilities are simply added as individual criteria to established supplier-selection models. This treatment may overlook their potential influence on other criteria. Human-machine collaboration, for example, may be scored alongside cost and delivery without considering how it could affect operational performance or resilience. Such an approach limits the ability of the evaluation model to reflect the interconnected nature of Industry 5.0 requirements. A more integrated supplier-selection framework is therefore needed.

3.0 MATERIALS AND METHODS

The present review addresses this gap by focusing on the intersection of sustainability criteria, MCDM methodologies, and Industry 5.0 enablers within automotive supplier selection**.** Quantitative coding is also used to assess the extent to which these elements have been incorporated into the literature. The review therefore considers not only which criteria and methods have been reported, but also how extensively Industry 5.0 considerations have been integrated into supplier-selection research. This provides a clearer basis for identifying the

methodological and research gaps addressed by the present study.

3.1 Research Design and Systematic Literature Review Framework

This study employed a Systematic Literature Review (SLR) to examine research on sustainable supplier selection in the automotive industry, with particular attention to the Industry 5.0 paradigm. An SLR was considered appropriate because it provides a structured approach for identifying, screening, and synthesizing relevant studies from a defined body of literature (Tranfield *et al.*, 2003). Unlike a conventional narrative review, the process follows predefined procedures, making the selection and analysis of studies more transparent and reproducible.

The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) framework (Page *et al.*, 2021). PRISMA was used to organize and report the review process through the stages of identification, screening, eligibility assessment, and inclusion. The framework also provides a clear record of the number of studies considered and the reasons for their exclusion.

The review was guided by three research questions:

RQ1: Which sustainability criteria are most commonly used in supplier selection within the automotive industry?

RQ2: What decision-making techniques, including hybrid MCDM approaches, have been used to evaluate and rank automotive suppliers?

RQ3: To what extent have Industry 5.0 enablers, including human-machine collaboration, digital resilience, and circular economy principles, been incorporated into automotive supplier selection?

To address these questions, five scholarly databases were searched namely, Scopus, Web of Science, ScienceDirect, IEEE Xplore, and SpringerLink. These databases were selected because they provide broad coverage of research in engineering, supply chain management, sustainability, and decision-making.

The search strategy combined keywords relating to supplier selection, the automotive industry, MCDM techniques, sustainability, and Industry 5.0. The Boolean search string applied across the databases, with appropriate adjustments to suit the syntax of each database, was:

(“supplier selection” OR “supplier evaluation”) AND (“automotive” OR “automobile”) AND (“multi-criteria decision-making” OR “MCDM” OR “AHP” OR “TOPSIS” OR “fuzzy”) AND (“sustainab*” OR “Industry 5.0” OR “human-centric*” OR “resilien*”)

The search produced 1,298 records across the five databases. Scopus returned 412 records, followed by Web of Science with 298, ScienceDirect with 245, SpringerLink with 187, and IEEE Xplore with 156. After removing 342 duplicate records, 956 records remained for title and abstract screening.

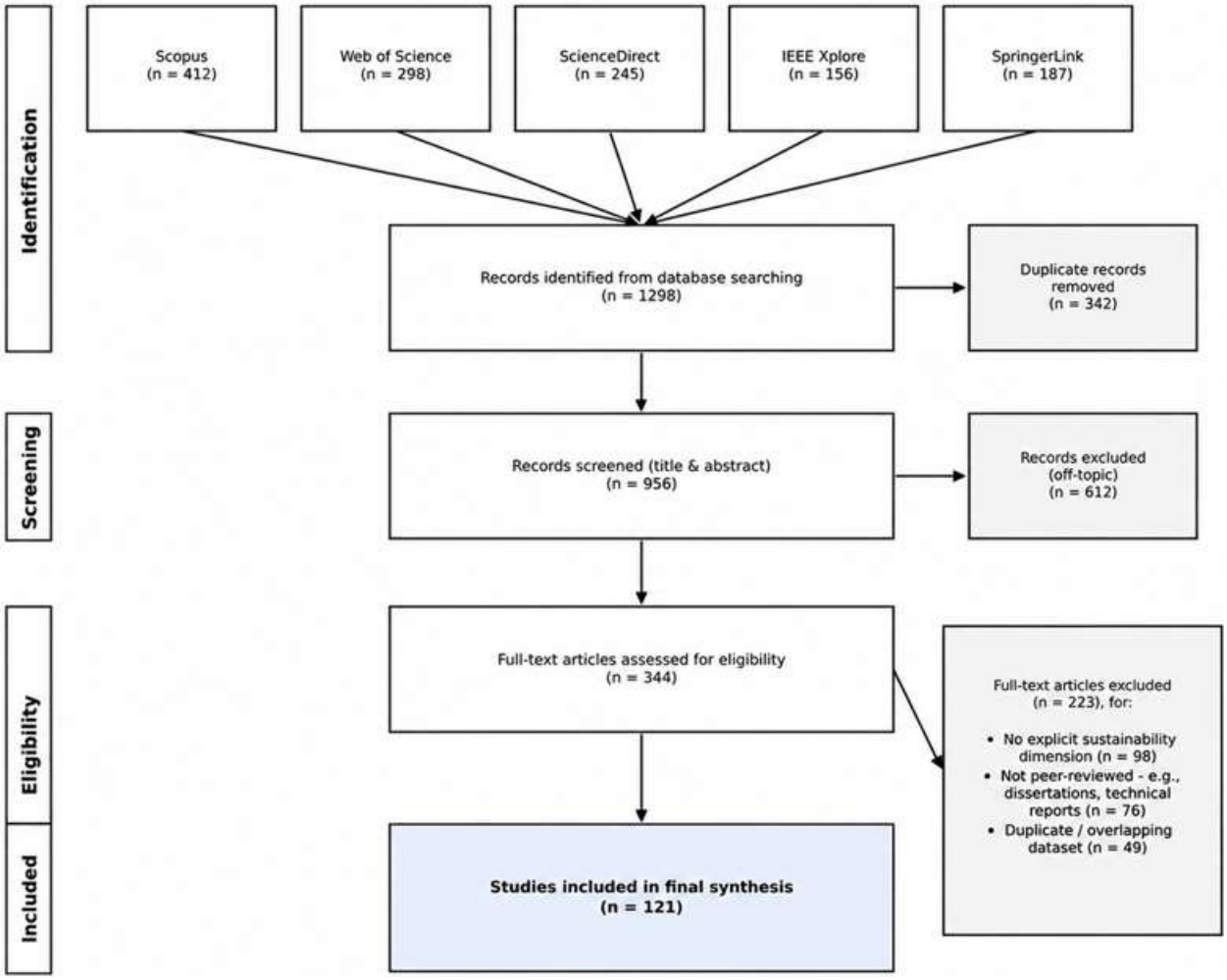


Figure 1: PRISMA flow diagram of the systematic literature review

Figure 1, presents the progression from the initial database search to the final set of studies included in the review. Of the 956 records screened at the title and abstract stage, 612 were excluded because they were not sufficiently related to the focus of the review. The remaining 344 articles were assessed through full-text review.

A further 223 articles were excluded at the eligibility stage. These included 98 studies that did not contain an explicit sustainability dimension, 76 that were not peer-reviewed publications, and 49 that were duplicate or overlapping datasets. The screening process therefore resulted in 121 studies being retained for the final synthesis.

3.2 Study Selection and Eligibility

The study selection process was conducted in two stages following the initial removal of duplicate records. The first stage involved screening the titles and abstracts of the retrieved studies. This assessment was used to remove studies that were clearly outside the scope of the review. The second stage involved a full-text assessment of the

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remaining studies against the predefined eligibility criteria.

Studies were included if they met the following criteria:

1. It addressed supplier selection or supplier evaluation within the automotive industry;
2. It considered at least one sustainability-related dimension;
3. It applied an MCDM or hybrid MCDM approach to supplier evaluation or selection;
4. It was published between 2000 and 2025;
5. It was published as a peer-reviewed journal article or conference proceeding; and
6. It was written in English.

Studies were excluded when they did not address sustainability in supplier evaluation, did not apply an MCDM-based approach, were not peer-reviewed, were duplicate or overlapping records, or fell outside the specified publication period.

After applying these criteria, 344 full-text articles were assessed for eligibility. Of these, 98 were excluded because they lacked an explicit sustainability dimension. A further 76 were excluded because they were not peer-reviewed, while 49 were removed because they represented duplicate or overlapping datasets. The final review therefore comprised 121 studies.

3.3 Data Extraction, Coding and Synthesis

A structured data-extraction form was developed to ensure that information was collected consistently from the 121 retained studies. The form captured bibliographic information, methodological characteristics, sustainability criteria, MCDM techniques, Industry 5.0 enablers, validation approaches, and the main contributions and limitations reported in each study.

The extracted information was analyzed using quantitative coding and qualitative thematic analysis. The quantitative analysis was used to identify the frequency and distribution of sustainability dimensions, decision-making methods, Industry 5.0 enablers, publication years, and geographical coverage.

The qualitative analysis was used to examine themes that could not be fully captured through frequency counts. Particular attention was given to the emergence of human-centered manufacturing, digital resilience, artificial intelligence, human-machine collaboration, and circular economy principles in supplier selection.

3.3.1 Coding of Sustainability and Industry 5.0 Dimensions

The 121 retained studies were reviewed to identify the sustainability dimensions and Industry 5.0 enablers considered in each study. A dimension or enabler was recorded when it was explicitly used as a supplier evaluation criterion or discussed as an implemented practice. General references in the introduction, background, or future

research sections were not considered sufficient evidence of adoption.

A study could report more than one sustainability dimension or Industry 5.0 enabler. The frequency and percentage of studies were therefore determined separately for each dimension or enabler, and the resulting percentages were not expected to sum to 100%. For example, a study that considered both environmental and economic criteria was counted under both dimensions. This approach allowed the review to show how widely the different sustainability dimensions and Industry 5.0 enablers have been incorporated into automotive supplier-selection research.

3.3.2 Classification of MCDM Approaches

The decision-making methods reported in the 121 retained studies were classified into three categories (classical MCDM, fuzzy MCDM, and hybrid MCDM). Classical MCDM referred to studies that applied conventional techniques such as AHP, TOPSIS, or VIKOR using crisp inputs without a fuzzy or similar uncertainty representation. Fuzzy MCDM covered studies in which a single MCDM technique was extended using fuzzy, intuitionistic fuzzy, or related approaches to represent uncertainty in the decision process. Hybrid MCDM included studies that combined two or more distinct MCDM techniques or integrated an MCDM method with an optimization or artificial intelligence approach.

The categories were defined as mutually exclusive to ensure a consistent classification across the reviewed studies. Thus, a study combining Fuzzy AHP and TOPSIS was classified as hybrid MCDM rather than fuzzy MCDM because it combined two distinct decision-making techniques. The resulting percentages therefore represent the distribution of the 121 studies across the three methodological categories and sum to 100%

3.3.3 Synthesis of the Evidence

The extracted information was analyzed using frequency counts, percentages, and descriptive summaries to identify patterns across the retained studies. The analysis examined the prevalence of sustainability dimensions, MCDM approaches, Industry 5.0 enablers, publication trends, and other characteristics captured during data extraction.

These numerical results were complemented by a qualitative review of how the identified criteria, methods, and Industry 5.0 enablers were applied in supplier-selection studies. This helped to identify emerging themes and developments that could not be fully explained by frequency counts alone. The findings from both forms of analysis were considered together to provide an overall picture of the existing literature and to identify gaps that support the need for a more adaptive approach to sustainable supplier selection.

4.0 RESULTS

4.1 Description and Publication Trends of the Reviewed Studies

A total of 121 peer reviewed studies published between 2000 and April 2025 were

included in the review. The studies came from 34 countries, with China, India, the United States, Germany, and Iran accounting for the largest contributions. This distribution indicates that research on sustainable supplier selection has attracted attention across several major automotive and manufacturing economies. However, the concentration of studies in a small number of countries also suggests that the literature is not evenly distributed geographically.

The publication type also shows a considerable presence of conference research. Journal articles accounted for approximately 62% of the reviewed studies, while conference papers represented 38% as demonstrated in Figure 2. The relatively large share of conference publications suggests that the topic remains an active area of research and development. It also indicates that a substantial proportion of the available research has been reported through conference outlets rather than journals.

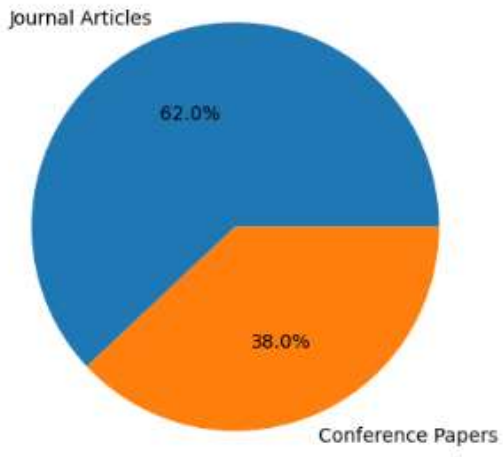


Figure 2: Publication Type Distribution

The distribution of publications over the review period revealed three main stages, as presented in Table 1. The first stage covers the early development of sustainable supplier selection research. The second represents a period of increasing application of MCDM approaches to supplier evaluation. The third begins in 2021 and reflects the growing relevance of Industry 5.0 within the research area. The 2021 boundary is particularly relevant because the European Commission formally introduced the Industry 5.0 concept during this period (Breque *et al.*, 2021). It therefore provides a reasonable point for examining the emergence of Industry 5.0 related considerations in the literature.

The earlier boundary around 2010 and 2011 is used mainly to distinguish the early studies from the subsequent growth in publications. Unlike the 2021 boundary, it does not represent a specific external event. Instead, it provides a useful descriptive basis for examining how the research area developed over the review period.

4.1.1 Developmental Stages of the Literature

Developing Phase (2000–2010)

The early literature focused on incorporating sustainability into traditional supplier selection. Environmental compliance received particular attention, alongside cost and supplier performance. At this stage, sustainability considerations were generally added to existing supplier evaluation frameworks rather than treated as an integrated decision structure.

Growth and Diversification (2011–2020)

The literature expanded considerably during this period, with greater use of MCDM techniques to address the growing complexity of supplier selection. Environmental, social, and economic criteria became more prominent, reflecting a broader adoption of the Triple Bottom Line perspective. Researchers also increasingly combined MCDM techniques to address uncertainty and the multiple dimensions involved in supplier evaluation.

Industry 5.0 Paradigm (2021-2025)

The most recent period indicates growing attention to Industry 5.0 considerations. Human machine collaboration, resilience, digital capabilities, and circularity began to appear alongside established sustainability criteria. However, their representation in the literature remains limited compared with traditional economic, environmental, and operational criteria. This suggests that Industry 5.0 is still an emerging area within sustainable supplier selection.

Taken together, the publication trend indicates a gradual broadening of supplier selection research. The focus has moved from conventional cost and performance considerations towards wider sustainability requirements and, more recently, Industry 5.0 capabilities. This progression provides the context for examining whether existing supplier selection models are sufficiently responsive to the changing requirements of automotive supply chains.

4.2 Decision-Making Method Trends

The reviewed studies illustrate a gradual development in the use of multi-criteria decision-making (MCDM) techniques for sustainable supplier selection. Classical MCDM methods accounted for 42% of the reviewed studies as presented in Figure 3, making them the most frequently used category. AHP, TOPSIS, and VIKOR were among the methods reported in this group. Their continued use reflects the established role of conventional MCDM techniques in weighting criteria and ranking supplier alternatives. Their relatively simple structure also makes the results easier to interpret and apply.

Fuzzy MCDM methods accounted for 31% of the studies. These approaches were mainly used to address uncertainty and subjectivity in expert assessments. Fuzzy representations allow linguistic judgements to be incorporated into the decision process and provide a way of handling imprecise information (Kannan *et al.*, 2020).

Table 1: Evolutionary stages of sustainable supplier selection

Research Stage	Time Period	Dominant Focus	Characteristics	Key Limitations
Developing Phase	2000–2010	Environmental compliance and cost performance trade-offs	Adaptation of traditional supplier evaluation models with basic green criteria	Narrow sustainability scope, static evaluation, limited decision complexity
Growth and Diversification	2011–2020	Triple bottom line sustainability integration	Expansion of MCDM methods, fuzzy logic, and early hybrid qualitative–quantitative models	Predominantly static weighting, limited real-time data integration
Industry 5.0 Paradigm	2021–2025	Human-centricity, resilience, and circular supply networks	Early exploration of intelligent, adaptive, and digitally enabled decision frameworks	Sparse empirical validation, weak integration of adaptivity and Digital Twins

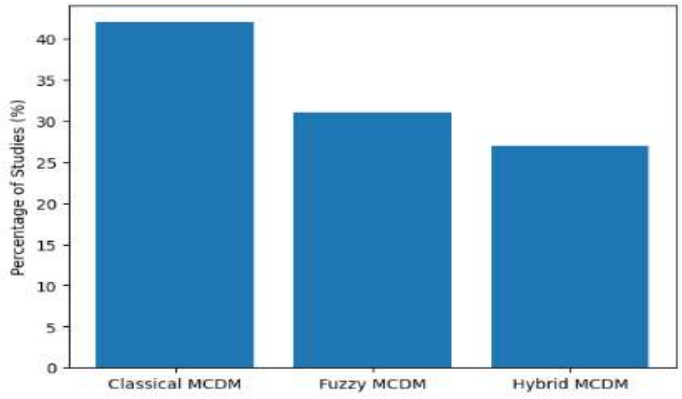


Figure 3: Decision Making Trend

This development reflects the recognition that supplier evaluation often involves judgements that cannot be expressed precisely through crisp numerical values.

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The remaining 27% of the studies used hybrid MCDM approaches by combine different techniques to address multiple aspects of the supplier-selection problem. For example, DEMATEL can be used to examine causal relationships among criteria, while ANP can capture interdependencies. Other studies have combined MCDM with optimization or artificial intelligence methods, as demonstrated by approaches such as BWM-DEA, Fuzzy DEMATEL-ANP, and ANN-TOPSIS (Rezaei *et al.*, 2016; Okwu and Tartibu, 2020). The use of hybrid approaches therefore reflects an increasing interest in combining complementary analytical capabilities within a single decision framework.

Overall, the distribution revealed that classical MCDM remains the dominant approach, followed by fuzzy and hybrid methods. The presence of fuzzy and hybrid approaches also indicates a gradual move towards models that can address uncertainty, criterion relationships, and more complex decision requirements. However, the relatively smaller share of hybrid methods suggests that the integration of multiple analytical techniques is still less common than the use of established single-method approaches. This finding is relevant to the present study because the proposed framework combines different methods to address uncertainty, causal relationships, changing supplier conditions, and supplier ranking within a single decision process.

4.3 Sustainability Criteria Trends

Figure 4 demonstrated a strong emphasis on economic and environmental criteria across the reviewed studies. Economic criteria, including cost, delivery performance, and quality, were reported in 93% of the studies. Their continued prominence confirms their established role in supplier evaluation and is consistent with findings reported by Kaur and Singh (2021) and Mohammed *et al.* (2019).

Environmental criteria had the highest representation, appearing in 96% of the studies. Common examples included emissions reduction, energy efficiency, and waste management. This high representation reflects the strong attention given to environmental performance in sustainable supplier selection and its connection with requirements such as environmental management and circular economy practices (Govindan *et al.*, 2015; Brandenburg *et al.*, 2014).

Social criteria were reported in 41% of the studies. These included labour rights, ethical sourcing, community engagement, and worker welfare. Although social considerations form an important part of sustainable and human-centered supplier evaluation, their representation was considerably lower than that of economic and environmental criteria. This finding is consistent with the concerns raised by Yawar and Seuring (2017) regarding the treatment of social sustainability in supply chain research.

Industry 5.0 readiness had the lowest representation, appearing in only 27% of the reviewed studies. The identified criteria included the adoption of collaborative robots, digital resilience, and artificial intelligence. This result suggests that Industry 5.0

capabilities remain an emerging area within supplier-selection research compared with the more established economic and environmental dimensions.

Collectively, the findings indicate a clear imbalance in the coverage of the four dimensions. Economic and environmental criteria are already well established in the literature, whereas social and Industry 5.0 readiness criteria receive considerably less attention. This pattern indicates that supplier-selection research has not yet fully reflected the broader human-centered, resilient, and technology-enabled requirements associated with Industry 5.0.

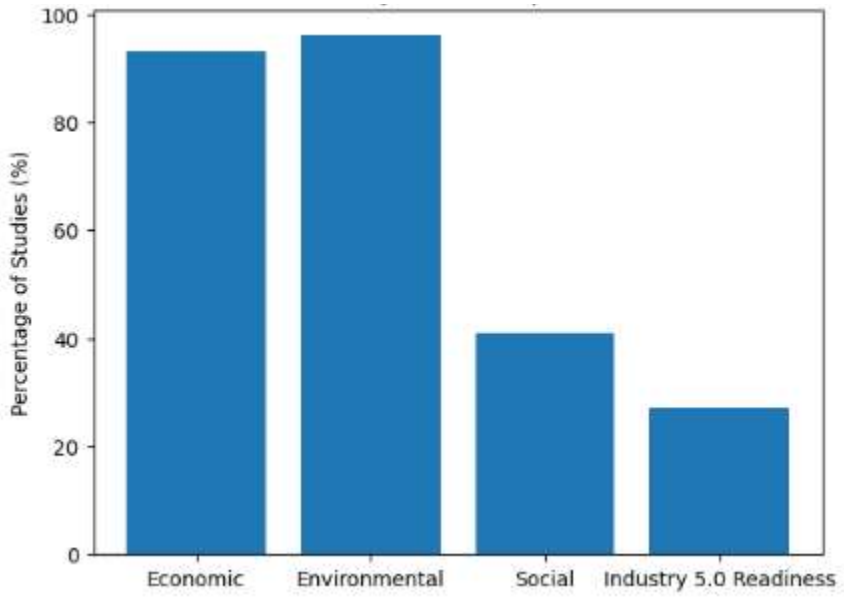


Figure 4: Sustainability Criteria Representation

4.4 Incorporation of Industry 5.0 Enablers

The review demonstrated that the incorporation of Industry 5.0 enablers into sustainable supplier selection remains limited and uneven. As presented in Figure 5, human machine collaboration was identified in only 14% of the reviewed studies. The criteria reported under this area mainly concerned the ability of suppliers to support collaboration between workers and advanced technologies. Its limited representation suggests that the human centered aspect of Industry 5.0 has received relatively little attention in supplier selection research (Nahavandi, 2019; Demir *et al.*, 2023).

Digital resilience appeared in 19% of the studies, with reported considerations including cybersecurity, adaptive supply-chain capabilities, and the use of real-time data analytics. Several studies linked these capabilities to the use of IoT, big data, and artificial intelligence to improve supply chain responsiveness and support decision making during disruptions (Bag *et al.*, 2021; Kamble *et al.*, 2022).

Circular economy and regenerative manufacturing had the highest representation among the three enablers, appearing in 23% of the studies. The identified considerations included resource efficiency, waste reduction, recycling, and closed loop supply chain practices. This level of representation indicates that circularity has received greater attention within sustainable supplier selection than the other Industry 5.0 enablers examined in the review (Jabbour *et al.*, 2021). It is also consistent with Lopes de Sousa Jabbour *et al.* (2023), who emphasized the importance of combining technological and human considerations when implementing circular practices in Industry 5.0 environments.

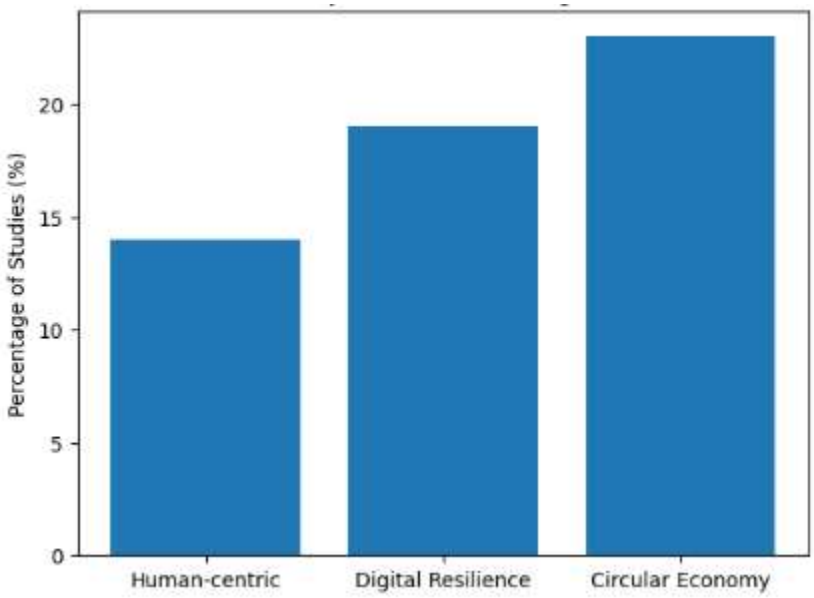


Figure 5: Industry 5.0 Enablers

Overall, the findings revealed that Industry 5.0 enablers remain underrepresented in supplier selection research, although their presence is becoming more visible. Circular economy and regenerative manufacturing had the highest representation at 23%, followed by digital resilience at 19% and human machine collaboration at 14%. The results therefore indicate that existing research has given greater attention to resource and circularity considerations than to the human and resilience dimensions of Industry 5.0.

This finding is important for the present study because it demonstrated that Industry 5.0 has not yet been fully integrated into sustainable supplier selection. In particular, the limited representation of human machine collaboration and digital resilience points to areas that require greater consideration when developing supplier evaluation frameworks for changing automotive supply chain conditions.

4.5 Synthesis of Findings across the Research Questions

The findings provide a consistent picture of how sustainable supplier selection has developed within the automotive context. Economic and environmental criteria remain the most widely represented, while social and Industry 5.0 related criteria receive considerably less attention. A similar pattern can be observed in the decision-making methods used in the literature. Classical MCDM approaches remain dominant, although fuzzy and hybrid methods have gained increasing attention for addressing uncertainty and the complexity of supplier evaluation.

The limited representation of some criteria and methods does not necessarily indicate that they are considered less important. Instead, it suggests that established and readily measurable aspects of supplier performance continue to receive greater attention in the literature. Economic and environmental criteria are supported by well-established measures and reporting practices, whereas social and human-centered capabilities can be more difficult to define and assess consistently. In the same way, conventional MCDM techniques remain widely used because their structures are familiar and relatively straightforward to apply, while more integrated approaches require the combination of several analytical procedures.

The findings also indicated that Industry 5.0 considerations have not yet been fully incorporated into sustainable supplier selection. Circular economy and regenerative manufacturing were the most frequently represented Industry 5.0 related areas, followed by digital resilience and human machine collaboration. Their relatively low representation compared with economic and environmental criteria indicates that supplier evaluation research is still largely based on established sustainability requirements rather than the broader human-centered, resilient, and technology-enabled perspective promoted by Industry 5.0.

Taken together, the evidence suggests that the literature has progressed from conventional supplier evaluation towards more sophisticated and sustainability-oriented decision models, but this development remains incomplete. Uncertainty is increasingly addressed through fuzzy methods, relationships among criteria are being considered through hybrid approaches, and Industry 5.0 capabilities are beginning to appear in supplier evaluation. However, these developments have generally occurred as separate extensions of existing models rather than as a fully integrated approach capable of responding to changing supplier conditions.

The three research questions can therefore be answered collectively. The literature places strongest emphasis on economic and environmental criteria, while social and Industry 5.0 related dimensions remain less represented. Classical MCDM methods continue to account for the largest share of applications, followed by fuzzy and hybrid approaches. Industry 5.0 enablers are also present but remain unevenly incorporated, with circular economy considerations

receiving greater attention than digital resilience and human machine collaboration.

These findings highlight a clear opportunity for further development of sustainable supplier selection. A more comprehensive approach should be capable of handling uncertain expert judgement, recognizing relationships among criteria, incorporating Industry 5.0 requirements, and responding to changes in supplier performance over time.

5.0 CONCLUSION

This study reviewed 121 peer-reviewed publications published between 2000 and April 2025 to examine the development of sustainable supplier selection in the automotive sector. The review considered the criteria used to evaluate suppliers, the MCDM approaches applied, and the extent to which Industry 5.0 principles have entered the decision-making process.

The evidence revealed that economic and environmental considerations remain the strongest focus of the literature. Social criteria receive less attention, while Industry 5.0 capabilities such as human-machine collaboration and digital resilience are still emerging. The review also illustrated a progression in decision-making methods, from conventional MCDM techniques towards fuzzy and hybrid approaches that provide greater capacity to deal with uncertainty and complex evaluation requirements.

Despite these developments, supplier selection research has not yet fully reflected the changing conditions associated with Industry 5.0. Most existing approaches remain centered on relatively established evaluation structures, with limited consideration of how supplier performance and criterion importance may change over time. This provides a clear basis for the adaptive Digital Twin-guided framework developed in this study, which brings together uncertainty handling, criterion relationships, changing supplier conditions, and supplier ranking within a single decision-support process.

5.1 Limitations of the Review

The findings should be considered in light of several limitations. The search was restricted to English-language, peer-reviewed publications indexed in five databases. Relevant studies published in other languages or available through databases outside the selected sources may therefore have been missed. This may also have influenced the geographical distribution observed in the review.

The exclusion of dissertations, technical reports, and other forms of grey literature represents another limitation. Although this helped maintain a consistent academic evidence base, some practical applications of supplier-selection models may have been reported outside peer-reviewed publications and were consequently not captured.

Finally, the search covered publications available up to April 2025. Developments after this date are therefore outside the scope of the review. This is particularly relevant to Industry 5.0, where technologies and applications continue to evolve rapidly.

5.2 Theoretical and Practical Implications

The review contributes to the literature by bringing together three areas that are often examined separately, namely sustainability criteria, MCDM approaches, and Industry 5.0 capabilities. It provides a clearer picture of how these elements have been incorporated into automotive supplier-selection research and highlights the uneven development across them.

The review also provides a consistent basis for treating Technological/Industry 5.0 Readiness as a distinct area of supplier evaluation. This helps address the variation in terminology found across previous studies and provides a useful foundation for subsequent research on technology-enabled supplier assessment.

From a practical perspective, the findings can help automotive organizations reconsider the scope of their supplier evaluation systems. Traditional measures such as cost, quality, delivery, and environmental performance remain important, but they may not provide a complete picture of supplier suitability under changing Industry 5.0 conditions. Procurement and supply chain managers may therefore need to give greater consideration to capabilities related to resilience, digitalization, human-machine collaboration, and circularity.

5.3 Future Research Directions

Several areas deserve further attention. Future studies should test adaptive supplier-selection models in realistic automotive supply chain environments and examine how supplier rankings respond to changes in operational conditions. Greater use of longitudinal and real-world data would also strengthen the evidence supporting dynamic decision-making approaches.

Social sustainability represents another important research opportunity. More reliable and independently verifiable measures could improve the assessment of social performance, particularly across multiple supplier tiers where information may be difficult to obtain.

Finally, future models should also examine the relationships between Industry 5.0 capabilities and established supplier-selection criteria. Human-machine collaboration, digital resilience, circularity, and technological readiness may influence other aspects of supplier performance rather than functioning simply as independent criteria. Understanding these relationships could lead to more meaningful supplier evaluation structures.

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