CHAPTER 72

The Role of AI in Modern Supply Chain Optimization

*Prasad Mahale**

ABSTRACT

The rapid progress of the Fourth Industrial Revolution has highlighted the critical role of Artificial Intelligence (AI) in driving digital transformation across industries. Recent global disruptions, particularly health crises, have reinforced the necessity of developing resilient and adaptive supply chains that can withstand unforeseen challenges. For organizations, this requires building strong supplier networks that ensure operational continuity and sustainability, while suppliers must enhance transparency and communicate their capabilities effectively to remain competitive. Traditional procurement approaches focused only on cost reduction are no longer adequate; instead, a shift toward strategies emphasizing long-term stability and risk management is essential. AI-based solutions now serve as vital tools for planning, forecasting, and optimizing decisions in supply chain management. Among these, Genetic Algorithms (GA) enable the simultaneous evaluation of multiple criteria—including pricing, delivery performance, regulatory compliance, and quality standards—to identify the most suitable suppliers. In parallel, Large Language Models (LLMs) provide the ability to analyze unstructured data, offering deeper insights and more refined supplier evaluations. By integrating such techniques into decision support systems, organizations can enhance both accuracy and efficiency in procurement processes. This paper emphasizes the strategic importance of AI in modern supply chain optimization and demonstrates how its application fosters resilience, competitiveness, and sustainability.

Keywords: Supply Chain Management (SCM); Artificial Intelligence (AI); Large Language Models (LLMs); Genetic Algorithm (GA).

1.0 Introduction

In today's highly competitive business landscape, organizations rely heavily on effective supplier selection, supplier management, and supplier development to remain sustainable and efficient. Traditionally, supplier selection has been treated as a one-time activity, with limited emphasis on continuous assessment.

* *Ph.D. Scholar, MBA Department, Dr. Moonje Institute of Management and Computer Studies, Nashik, Maharashtra, India (E-mail: prasad23_2000@yahoo.com)*

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

Supplier audits, which are essential to ensure compliance with required quality and service standards, are often overlooked. Regular evaluation through audits, performance scoring, and supplier assessments—collectively part of Supplier Relationship Management (SRM)—provides valuable insights that guide decisions about maintaining or discontinuing supplier partnerships. Periodic reviews not only highlight areas for improvement but also create a fair and competitive environment for suppliers [1].

Expanding the supplier base to include local, national, and international players enhances procurement efficiency. However, for a partnership to be successful, compatibility between the supplier's business practices, culture, and the purchasing organization's policies is vital [2].

Alignment of expertise with organizational needs is another critical factor. Wrong choices in supplier selection can cause severe financial setbacks, disrupt business operations, and undermine product quality. These risks are particularly significant in industries that directly affect human life—such as healthcare, food, and transportation—where even minor supplier deficiencies can result in large-scale disruptions. The COVID-19 pandemic highlighted how fragile supply networks can become under such conditions. Poor supplier selection can further lead to reduced product quality, missed deliveries, and additional costs caused by production delays, all of which negatively influence long-term organizational performance [3].

The integration of Artificial Intelligence (AI) into supplier selection processes brings transformative potential to supply chain management (SCM). AI enables real-time updates on supplier performance and supports continuous improvement, thereby ensuring the delivery of high-quality and consistent products or services. Organizations using AI can automate quality monitoring, identify the most adaptive suppliers, and adjust to changing market conditions more effectively. Beyond supplier selection, AI enhances overall decision-making in SCM through advanced data analysis, offering organizations faster and more reliable solutions. AI applications in SCM include timely order fulfillment, optimized inventory control, cost reduction, data protection, and improved coordination between buyers and suppliers. During the pandemic, these capabilities proved critical by enabling quicker, more accurate evaluations and stronger buyer-supplier connections. Despite these benefits, certain challenges remain in applying AI to supply chain operations, particularly in procurement and service processes [8].

To address such complexities, Genetic Algorithms (GA) have been widely applied. GA techniques improve decision-making efficiency and adaptability, making them valuable tools in SCM [9]. They are particularly useful in areas such as order and production management, product flow, and distribution planning. By developing predictive models and decision-support systems, GA helps organizations optimize operations. Studies indicate that

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

GA often outperforms alternative methods, and hybrid approaches have demonstrated even greater accuracy in optimizing distribution networks and supply flows [10].

2.0 Methodology

Gartner Analyst Noha Tohamy highlights that two fundamental elements of Artificial Intelligence—Augmentation and Automation—should be integrated into digital transformation initiatives in supply chain management (SCM). Augmentation refers to AI applications that support human activities, such as data analytics, virtual assistants, and software tools, primarily aimed at reducing errors arising from human bias. In contrast, automation involves systems that function entirely without human involvement, such as robots carrying out critical manufacturing operations [4]. For small and medium-sized enterprises (SMEs), effective supplier management poses challenges due to limited financial and human resources [12].

Therefore, cost-effective and practical digitalization strategies are essential for SMEs in the supplier selection process. Establishing clear and sector-specific criteria for evaluating suppliers is a crucial step in this direction. With the adoption of advanced AI tools and optimization methods, businesses can gradually move toward developing "smart factories." A noteworthy aspect of AI integration in supplier selection is the ability to adapt selection criteria to the unique demands of different industries. While general factors such as cost, delivery timelines, customs requirements, taxation, production methods, warranty provisions, and quality testing remain important, sector-specific customization further enhances supplier evaluation. Automating these complex assessments enables Supplier Relationship Management (SRM) systems to evolve into intelligent platforms, leading to wider acceptance and greater usage among businesses.

3.0 AI methods in SCM

In supply chain management (SCM), two of the most commonly utilized artificial intelligence techniques are expert systems and meta-heuristic algorithms. Expert systems are designed to replicate the reasoning of human specialists and support decision-making in situations where not all information may be available at the time of modeling [5]. These systems are widely applied because they ensure consistency in outcomes, preserve accumulated knowledge, and provide long-term cost efficiency. Consequently, many SCM software developers integrate expert systems into their platforms, applying them in areas such as supplier selection and supplier relationship management. However, their reliance on deterministic models makes them less effective in unpredictable environments. To remain

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

useful, they must be regularly updated and adjusted to reflect changing circumstances. This limitation underscores the need for approaches that enable faster, more objective, and optimized supplier selection.

Meta-heuristic algorithms, on the other hand, are particularly well-suited for complex optimization problems. Among these, Genetic Algorithms (GAs) have emerged as one of the most widely adopted methods due to their ability to quickly generate practical solutions [6]. Inspired by Darwin's evolutionary principles, GAs function by allowing the "fittest" solutions to survive and evolve. As noted by Goldberg, GAs provide two distinct advantages: they explore multiple solutions simultaneously, which shortens the time required to reach a decision, and they are adaptable to uncertain or nondeterministic scenarios [7]. When applied to SCM, GA-based approaches enable organizations to evaluate multiple supplier-related criteria simultaneously. This includes general factors such as cost, delivery performance, taxes, warranty terms, and production methods, as well as sector-specific considerations related to product quality. Automating such evaluations helps Supplier Relationship Management (SRM) systems become more intelligent, accessible, and efficient, even for businesses with lower levels of digital maturity. Moreover, by combining GAs with machine learning (ML), organizations can transform passive data into actionable insights, creating transparent and reliable supplier selection processes. Such systems are capable of generating multiple "best supplier" scenarios, offering businesses not only faster but also fairer and more accurate decision-making support.

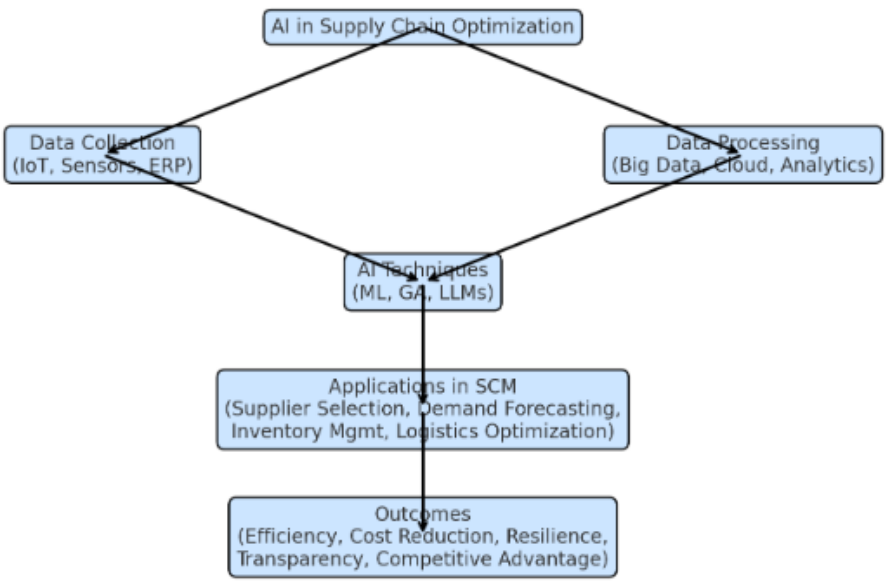
4.0 Genetic Algorithm (GA) in SCM

A Genetic Algorithm (GA) begins by creating an initial population of randomly generated chromosomes, each representing a potential solution within the problem space. To apply GA effectively, it is first necessary to define the chromosome structure in relation to the problem being addressed. As chromosomes consist of genes, appropriate coding must be selected depending on the characteristics of the problem. In the supplier selection context, chromosomes are represented as arrays. The index positions within the array correspond to suppliers, meaning the chromosome length is equal to the total number of suppliers. The gene values within the array indicate the company assigned to each supplier. Since companies are expressed as consecutive integers, each gene takes an integer value. Thus, the index of the chromosome identifies the supplier, while the gene value specifies the company with which that supplier is linked. When new chromosomes are generated during the evolutionary process, it is essential to verify that they satisfy the constraints of the problem. Any inconsistencies must be corrected to ensure valid and feasible solutions.

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

5.0 LLMs in the Digital Industry Revolution

Large Language Models (LLMs) have emerged as powerful tools in natural language processing and related domains, achieving impressive results in generating and interpreting text with coherence and contextual depth [11]. Their rapid progress has sparked extensive research across areas such as architectural design, training techniques, expansion of context windows, fine-tuning strategies, and the rise of multi-modal systems [12]. With the advent of Industry 4.0, where digital technologies are embedded into manufacturing and supply chain processes, the need for reliable and efficient decision-making frameworks has grown considerably. In this setting, LLMs offer strong potential to enhance supplier evaluation and supply chain planning. By examining large datasets—including supplier costs, delivery performance, production approaches, tax and customs implications, warranty terms, and quality checks—these models allow businesses to make more precise and informed choices [13].



Models like GPT and BERT have demonstrated the ability to incorporate diverse data sources, enabling organizations to assess supplier reliability based on historical performance and even forecast future outcomes [14]. Another strength of LLMs lies in their ability to automate the handling of unstructured information, such as contracts, emails, and communication records. This reduces the reliance on manual review while minimizing bias and error, ultimately accelerating supplier selection and improving accuracy [15]. Such applications contribute directly to strategic supply chain decision-making by enhancing

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

efficiency, reducing risk, and strengthening trust in supplier relationships. In practice, small and medium-sized enterprises (SMEs) often face constraints in resources for supplier management. When supported by enterprise resource planning (ERP) data, machine learning, and predictive analytics, LLMs can form the foundation of decision-support systems that improve supplier selection, diversification, and overall relationship management. Data from SRM activities—including audits, evaluations, and credit assessments—provides valuable input for these systems, fostering greater supply chain resilience, ethical practices, and sustainability.

Beyond supplier selection, LLMs are increasingly applied to optimize supply chain operations more broadly. Their predictive capabilities help anticipate demand fluctuations, detect bottlenecks, and design efficient transport routes. Importantly, their capacity to interpret natural language allows them to extract meaningful insights from unstructured sources, adding another layer of value [12]. One notable advancement is the OptiGuide framework developed by Li et al. [7], which combines LLMs with traditional optimization techniques. This system translates natural language queries into comprehensible outputs for supply chain optimization, allowing non-technical users to run "what-if" analyses with ease. OptiGuide demonstrates how integrating LLMs with optimization solvers can generate actionable insights, offering transparency and enhancing user trust. In practice, this integration strengthens logistics management, supplier collaboration, and scenario planning by reducing analysis time and providing timely responses to disruptions. Ultimately, such innovations not only streamline supply chain workflows but also reinforce confidence in the adoption of intelligent, automated systems.

6.0 Application

The integration of Artificial Intelligence (AI) into procurement and Supply Chain Management (SCM) holds significant potential to augment and automate human-driven practices. In the long term, AI can enable efficient and equitable Supplier Relationship Management (SRM) processes, transforming procurement practices across industries, particularly in public institutions, where such improvements may contribute to cost savings and job protection. Industrial and service enterprises (ISEs) must therefore proactively adopt AI technologies or risk being marginalized in an increasingly competitive environment. This study underscores the transformative role of AI in enhancing the efficiency, reliability, and resilience of supply chains.

Specifically, it highlights the contribution of Genetic Algorithms (GAs) and Large Language Models (LLMs) in optimizing supplier selection, managing supply chain operations, and mitigating risks. AI's ability to analyze vast, complex datasets and generate actionable insights facilitates the development of a robust supplier base that is both cost-

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

effective and adaptable to market fluctuations. The application of Genetic Algorithms enables the simultaneous evaluation of multiple criteria, such as price, lead time, production capacity, and quality standards, thereby ensuring optimal supplier selection. Such multi-objective optimization helps businesses minimize disruptions linked to supplier issues—an especially critical factor in sectors like healthcare, transportation, and food, where reliability is paramount. In parallel, Large Language Models provide sophisticated tools for processing unstructured data and extracting meaningful insights.

Leveraging LLMs enhances supplier assessment, optimizes logistics planning, and supports risk evaluation related to geopolitical conditions, tariffs, and external uncertainties. Their capability to interpret natural language and deliver coherent analyses positions LLMs as invaluable assets in strategic SCM decision-making. The practical implications are extensive. AI-driven supplier selection processes reduce manual intervention, minimize human error and bias, and foster transparent evaluations. Moreover, AI empowers organizations to build adaptive supply chains that respond dynamically to market disruptions, thereby safeguarding operational continuity and efficiency. Recent innovations further demonstrate AI's real-world relevance. For instance, software such as "Costifier" illustrates how AI can significantly improve cost estimation and optimization, particularly for SMEs seeking accessible efficiency-enhancing solutions. Likewise, the integration of IoT devices with AI techniques enables the collection of real-time data, which enhances forecasting accuracy and decision reliability in supply chain systems.

An experimental case in the Vietnamese Textile and Apparel (T&A) sector illustrates the effectiveness of LLMs such as DistilGPT-2 in supplier evaluation. Using natural language processing (NLP) techniques, the model successfully analyzed supplier performance data, identified key subsets of reliable suppliers, and provided nuanced recommendations. These results demonstrate the capacity of LLMs to process complex datasets, streamline supplier selection, and substantially reduce the time and resources required for traditional analyses. The findings confirm that incorporating LLMs in supplier selection yields measurable improvements in efficiency, precision, and cost-effectiveness. Beyond supplier evaluation, such models enhance broader SCM processes, contributing to improved operational performance and long-term strategic planning. The success of DistilGPT-2 in this context highlights the transformative potential of AI in industrial applications, reinforcing its value in building smarter, more competitive supply chains. As AI technologies continue to evolve, their deployment in supply chain management is expected to expand further, delivering faster, more reliable, and resource-efficient decision-making frameworks. This study strongly advocates for the broader adoption of AI-enabled supplier selection and SCM practices, recognizing their potential to create sustainable competitive advantages and drive superior operational outcomes across industries.

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

7.0 Conclusion

The incorporation of Artificial Intelligence (AI) into supply chain management extends beyond being a technological upgrade; it has become a strategic imperative in today's dynamic business landscape. Organizations that actively embrace AI tools within their supply chain processes are more likely to withstand future disruptions, streamline their operations, and sustain a competitive edge. The ability of AI to reshape procurement practices, especially within public sector institutions, highlights the importance of sustained research, innovation, and investment in this domain. For Industrial and Systems Engineers (ISEs), active involvement with these advancements is essential to unlock their full potential and contribute meaningfully to the ongoing transformation of the industry.

References

1. Kosasih, E. E., & Brintrup, A. (2021). Reinforcement learning provides a flexible approach for realistic supply chain safety stock optimisation. *arXiv*. Retrieved from https://arxiv.org/abs/2107.00913 arXiv
2. Shawon, R. E. R., Hasan, M. R., Rahman, M. A., Ghandri, M., Lamari, I. A., Kawsar, M., & Akter, R. (2025). Designing and deploying AI models for sustainable logistics optimization: A case study on eco-efficient supply chains in the USA. *arXiv*. Retrieved from https://arxiv.org/abs/2503.14556 arXiv
3. Ahn, H., Olivar, S., Mehta, H., & Song, Y. C. (2024). Generative probabilistic planning for optimizing supply chain networks. *arXiv*. Retrieved from https://arxiv.org/abs/2404.07511 arXiv
4. Li, B., Mellou, K., Zhang, B., Pathuri, J., & Menache, I. (2023). Large language models for supply chain optimization. *arXiv*. Retrieved from https://arxiv.org/abs/2307.03875 arXiv
5. Achakzai, M. K., Rehman, A., Ahmed, A., & Haider, S. O. (2025). The role of artificial intelligence in transforming supply chain management: A focus on demand forecasting and inventory optimization. *The Critical Review of Social Sciences Studies, 3*(2), 622–637. https://doi.org/10.59075/vs86kw78 thecrsss.com
5. Shakya, R. K., Devarajan, K., Samuel, S. M., Kumar, S., & Swathi, T. V. S. S. (2023). The role of artificial intelligence and machine learning in supply chain optimization: A systematic review. *Journal of Harbin Engineering University, 44*(7). harbinengineeringjournal.com
6. Kushtia, H. J. (2024). The integration of artificial intelligence in supply chain management: A comprehensive review. *ORGANIZE: Journal of Economics,*

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*

Management and Finance, 4(1). https://doi.org/10.58355/organize.v4i1.153 organize.pdfaii.org

7. Varma, K. (year not specified). Artificial intelligence in supply chain optimization: A review of current practices. *International Journal of Machine Learning for Sustainable Development*. ijsdcs.com
8. Alomar, M. A. (2022). Performance optimization of industrial supply chain using artificial intelligence. *Computational Intelligence and Neuroscience, 2022*(9306265), Article ID 9306265. https://doi.org/10.1155/2022/9306265 Stecab Publishing
9. Amellal, I., Amellal, A., Seghiouer, H., & Ech-charrat, M. R. (2024). An integrated approach for modern supply chain management: Utilizing advanced machine learning models for sentiment analysis, demand forecasting, and probabilistic price prediction. *Decision Science Letters, 13*, 237–248. https://doi.org/10.5267/dsl.2023.9.003 Stecab Publishing
10. Belhadi, A., Kamble, S., Fosso Wamba, S., & Queiroz, M. M. (2022). Building supply-chain resilience: An artificial intelligence-based technique and decision-making framework. *International Journal of Production Research, 60*(14), 4487–4507.
11. Judijanto, L., & Rosalia, O. (year not specified). The role of artificial intelligence in the optimization of supply chain management. *Maneggio*. https://doi.org/10.62872/e089x834 nawalaeducation.com
12. Wamba Fosso, S., Queiroz, M., Guthrie, C., & Braganza, A. (2022). Industry experiences of artificial intelligence (AI): Benefits and challenges in operations and supply chain management. *Production Planning & Control*. Wikipedia
13. Awasthi, S. (2024). Artificial intelligence in supply chain management. *Journal of Student Research, 13*(1). https://doi.org/10.47611/jsrhs.v13i1.5996 Journal of Student ResearchWamba-Taguimdje, S.-L., Wamba, S. F., Kamdjoug, J. R. K., & Wanko, C. E. T. (2020). Influence of artificial intelligence (AI) on firm performance: The business value of AI-based transformation projects. *Business Process Management Journal*.
14. Abaku, E. A., Edunjobi, T. E., & Odimarha, A. C. (2024). Theoretical approaches to AI in supply chain optimization: Pathways to efficiency and resilience. International Journal of Science and Technology Research Archive, 6(1), 92–107.
15. Rodriguez, C. (2025). Artificial Intelligence in Supply Chain Optimization: Combining Operations Research, Data Science, and Logistics. Global Multidisciplinary Perspectives Journal, 2(1), 8–11.
16. Bhavikatta, N. B. (2025). The Intelligent Supply Chain: Leveraging AI and ML for Operational Excellence. International Journal of Computer Science and Mobile Computing, 14(6), 56–66

DOI: 10.17492/JPI/ICISI2025/251272 *ISBN: 978-93-49790-69-8*