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Soft Computing Applications for Supply Chain Management: A Survey

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Abstract

Modern supply chain management is dynamic and becoming more complicated, which creates major problems for efficiency, flexibility, and decision-making. In situations involving unpredictable, imprecise, or quickly shifting supply and demand, traditional optimization and analytical techniques might be inadequate. In consideration of these difficulties, this study investigates the use of soft computing methods as effective alternatives for simulating and resolving actual supply chain management issues. These methods include fuzzy logic, genetic algorithms, artificial neural networks, and swarm intelligence. These methods perform especially well for improving the supply chain in several areas, such as demand forecasting, inventory management, logistics network design, distribution planning, and supplier selection and assessment. Organizations may develop more adaptable, reliable, and economic decision-making processes by utilizing self-learning, approximate reasoning, and adaptive characteristics of soft computing techniques. Consequently, this makes supply chain systems more flexible, adaptable, and responsive overall in the face of uncertainty and competitiveness globally.

Keywords: Soft Computing; Supply Chain Management; Supply Chain; Genetic Algorithms; Fuzzy Logic; Evolutionay Algorithms; Uncertainty.

1 | Introduction

The requirement for intelligent and adaptable solutions has grown in importance as global supply chains (SCs) have more and more difficulties, including process complexity, demand fluctuations, and environmental disruptions. Soft computing has emerged as one of the most effective techniques, providing methods and tools that can handle data complexity and ambiguity, improving decision-making at every SC stage. Fuzzy logic (FL), artificial neural networks (ANNs), evolutionary algorithms (EAs), and adaptive neuro-fuzzy inference systems (ANFIS) are just a few of the methods that fall under the umbrella of soft computing. These methods are used in many aspects of supply chain management (SCM), such as scheduling transportation and production, optimizing inventory, choosing suppliers, and anticipating demand. In contrast to conventional systems, a recent study showed how combining block chain technology with ANFIS benefited SC performance in the poultry sector, resulting in a 15% decrease in delivery times and increased operational efficiency [1]. Therefore, soft computing methods have greatly improved SC resilience in times of crisis, including the COVID-19 pandemic and disruptions brought on by climate change. According to a

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study, utilizing block chain and artificial intelligence (AI) could increase the financial SC's resilience to environmental changes [2].

Soft computing has made it possible to create sophisticated models in the field of smart logistics that use methods like support vector clustering to enhance demand forecasting and inventory control, which lowers costs and enhances operational efficiency [3]. Furthermore, recent evaluations have examined greater applications of AI in SC management, highlighting both the advantages and difficulties of implementing these technologies. Better risk management, enhanced end-to-end visibility, and greater alignment with sustainability objectives are a few of them [4]. Collectively, these studies highlight the critical role that soft computing approaches play in improving SCs' performance and flexibility, establishing them as important tools to meet upcoming obstacles in this field.

An overview of the SC and SCM in section 2 is given in the background part of this survey. Soft computing and its uses are then examined in Section 3. Section 4 then discusses the SCM procedures where these soft computing techniques can be used. Section 5 concludes by summarizing the results and outlining potential directions for future research.

2 | Background

2.1 | Supply Chain

A SC is a network of organizations, individuals, activities, data, and resources that work together to produce and deliver goods and services from suppliers to consumers [5]. It includes information, materials, and financial flows between suppliers, manufacturers, distributors, retailers, and final customers [6]. The planning, execution, and regulation of the effective movement and storage of products, services, and associated data from the point of origin to the point of consumption in order to satisfy consumer demands is what the Council of Supply Chain Management Professionals (CSCMP) defines as SCM[5]. The idea of SCM has changed over time, moving from concentrating internal operational efficiency to incorporating digital transformation and wider integration: standard stage: centered on internal operations including distribution and production, integrated stage: placed a strong emphasis on coordination and cooperation among SC participants [5], and digital stage: using cutting-edge technology to improve SC agility and responsiveness, such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics.

SCs are essential for gaining a competitive edge because they increase operational efficiency, which lowers costs and improves productivity; they also improve customer satisfaction by providing the right items at the right time with the appropriate quality; and they are able to adapt to changes in the market. Flexibility is adapting to changes in supply and demand as well as encouraging innovation, which means making it easier to create and launch new goods and services.

2.1.1 | Supply Chain Stages and Components

According to Figure 1, the SC has multiple interrelated phases, each of which is essential to maintaining smooth operation:

- The suppliers: Supply the components and raw materials needed for manufacture.
- Businesses: Utilize a variety of production techniques to turn raw resources into final goods.
- Distributors: Take care of the final products' delivery, storage, and distribution to traders or clients [7].
- Retailers: Provide final goods directly to customers [8].
- Customers: The people who purchase the goods or services in the end.

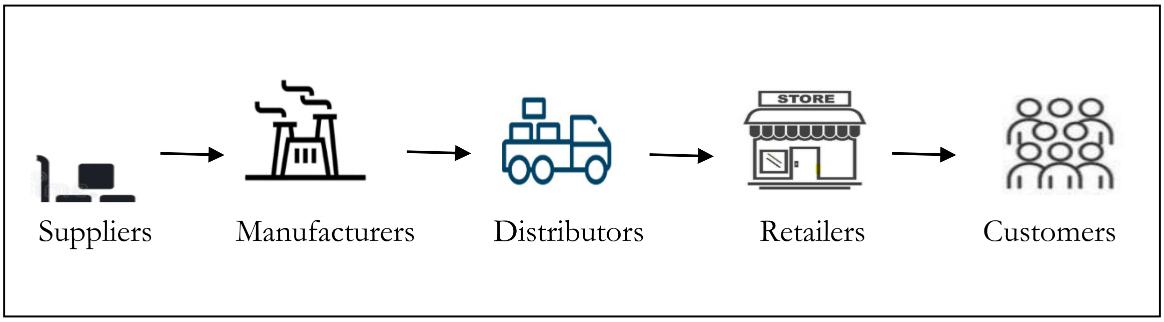

Figure 1. Supply Chain Processes.

For the SC to function as efficiently as possible, the flow of commodities, information, and funds must be properly coordinated at every step. A SC's essential elements are as follows: Demand planning is the process of projecting future product demand to direct distribution and manufacturing [9], inventory management is keeping the right amount of inventory on hand to satisfy demand without going overboard [10], logistics: The effective administration of delivery, warehousing, and transportation procedures, relationship management for suppliers and customers: establishing cooperative, long-term relationships with SC participants, and finally information Technology: Using digital technology and IT systems to improve coordination and transparency [6] see Figure 2.

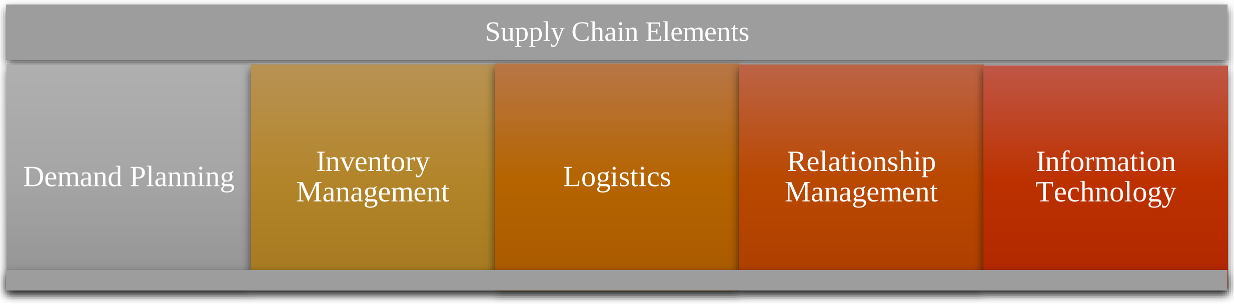

Figure 2. Elements of Supply Chain.

2.2 | Supply Chain Management

SCM is the strategic coordination of business operations and strategies throughout the SC with the goal of enhancing the long-term performance of both individual businesses and the SC overall [11]. It involves managing the movement of resources, data, and funds from suppliers of raw materials via producers and distributors to the end user. To gain a competitive advantage, SCM relates important company activities like production, distribution, procurement, and customer service.

SCM contains a number of essential tasks:

- Procurement management is the effective sourcing and acquisition of components and raw materials.
- Production planning is the process of organizing and managing production processes to satisfy consumer_demand.
- Inventory management is the process of balancing stock levels to prevent excess or shortages.
- Distribution and logistics: managing order fulfillment, storage, and transportation.
- Information management: exchanging up-to-date information and analysis to make intelligent decisions.

3 | Soft Computing

The term soft computing describes a group of computer methods that address uncertainty and approximation with the goal of modeling and resolving real-world issues that are too complicated, nonlinear, or poorly defined for conventional "hard computing" methods. It incorporates techniques such as probabilistic reasoning, evolutionary computation, FL, neural networks (NNs), and GAs. Soft computing is more flexible and useful for real-world applications because, like the human brain, it tolerates a certain amount of imprecision and uncertainty, in contrast to hard computing, which demands a well-defined and exact solution. It is also a group of computer approaches designed to study and describe complicated phenomena that have proven difficult to deal with traditional methods. Combining human reasoning with learning skills in unpredictable settings is a novel technique [12]. The main methods of soft computing are summarized as follows.

3.1 | Neural Networks

A key component of soft computing are NNs, which include both artificial and biological systems that use networked nodes (neurons) to process information. The reason for their importance is that they may represent complicated, nonlinear, and high-dimensional interactions without the need for explicit programming or prior understanding of data distributions. Because they offer adaptable, fault-tolerant, and noise-resistant learning models, NNs are essential in the setting of soft computing, allowing intelligent systems to deal with ambiguity, uncertainty, and incomplete information. NNs allowed approximate reasoning, which is in complete harmony with Zadeh's soft computing theory, in contrast to hard computing approaches that depend on exact algorithms. Simple perceptron models provided more complex structures like Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Deep Neural Networks (DNNs) throughout time. Each of these architectures is tailored to a specific sort of input, such as time-series, pictures, or sequences. For instance, a thorough analysis of several ANN models and their uses in finance, medical diagnosis, and image processing was offered in [13]. Also, how ANNs can be combined with metaheuristic optimization methods like GAs and particle swarm optimization to enhance engineering and logistics performance was explained in [14]. The application of hybrid ANN systems in smart grid modeling and renewable energy forecasting was highlighted in [15].

3.2 | Fuzzy Logic

One of the fundamental elements of soft computing, which seeks to simulate human-like thinking and decision-making in the face of uncertainty, is FL. FL permits degrees of truth that fall between 0 and 1, in contrast to classical or binary logic, where variables must be true or false (1 or 0). This illustrates how people typically use uncertain or imprecise phrases like high, low, moderate, or approximately when interpreting information and making judgments in their daily lives. Since its introduction by Lotfi A. Zadeh in 1965, FL has seen significant progress and is now widely applied in a variety of complex and uncertain systems in the twenty-first century. It works especially effectively for issues with fuzzy borders or when human-like interpretation is essential. FL serves as a rule-based system using fuzzy sets, membership functions, fuzzy rules, and inference engines. Membership functions, which convert distinct values into degrees of membership, are used to fuzzify inputs in a fuzzy inference system (FIS). A rule base made up of IF-THEN fuzzy rules processes these next, followed by inference and defuzzification, producing a clear output. According to [16], fuzzy decision-making methods are becoming essential in domains such as healthcare decision systems, environmental monitoring, and SC optimization. One major advancement is the creation of Type-2 FL systems, which are more resistant to noisy real-time data since uncertainty is modeled even inside the membership functions [17]. For instance in [18], it was discovered that FL outperformed rigid classifiers in medical diagnostics by handling overlapping illness criteria and ambiguous symptoms, hence improving diagnostic accuracy. FL has emerged as an enabler of interpretable models in the context of

Explainable AI (XAI). Fuzzy systems offer visible rule-based reasoning in contrast to deep neural networks, which have opaque internal decision-making processes. This makes them ideal for safety-critical applications such as healthcare systems and driverless cars. The application of FL to develop human-centered, explainable AI agents that are able to express their thought processes is presented in [19].

3.3 | Genetic Algorithms

GAs are effective metaheuristic search and optimization methods which derive ideas from genetics and natural selection. As a fundamental part of soft computing, GAs offer adaptable and reliable solutions to multimodal, complicated, and nonlinear situations where traditional approaches frequently prove ineffective. Fundamentally, GAs simulate the process of natural evolution. To find optimal or nearly optimal solutions, a population of candidate solutions—individuals or chromosomes—is evolved over a number of generations. Beginning with a population that is formed at random, the algorithm applies genetic operators—selection, crossover, and mutation—to produce a new generation after assessing each individual's fitness using an objective function appropriate to the situation. Parents are chosen according to their fitness using selection processes like a roulette wheel, tournament selection, or rank-based approaches. While mutation introduces random changes to maintain genetic variety and prevent premature convergence, the crossover operator simulates biological recombination by combining segments of two parents to form children. GAs have advanced significantly as a result of their hybridization with other learning and optimization techniques. For example, hybrid GA-Fuzzy and GA-PSO (Particle Swarm Optimization) techniques have been investigated to increase convergence accuracy and speed in highly nonlinear domains [20].

In machine learning, GAs are being utilized more and more for hyper parameter optimization and feature selection, where they assist maintain or improve model accuracy while lowering computational cost [21]. The use of multi-objective genetic algorithms (MOGAs) to resolve issues with competing goals, including decreasing cost while maximizing performance or resilience, is another new development. In this field, NSGA-II (Non-dominated Sorting Genetic Algorithm II) and its successors are still commonly used frameworks for planning energy systems, optimizing routes, and planning medical treatments [22]. Adaptive GAs, which modify mutation or crossover rates during evolution, have demonstrated encouraging outcomes in dynamic or uncertain contexts. In real-time scheduling and cloud resource allocation tasks, where environmental elements change often, adaptive GAs perform better than static designs [23]. Furthermore, the use of genetic programming (GP), a variation of GA that generates programs or mathematical expressions rather than simple vectors, in symbolic regression has grown in popularity as explainable and interpretable models have emerged. GP-based models forecast and model complicated systems using mathematics that are easy for humans to understand [24]. From an engineering point of view, GAs have been effectively used in control systems, fault diagnosis, and structural design. They are employed in logistics and transportation to address Vehicle Routing Problems (VRPs) with time windows and capacity limitations, assisting businesses in improving delivery timetables and cutting fuel usage [25]. As seen in Figure 3 below, soft computing techniques involve a variety of creative techniques like NNs, FL, GAs, and other approaches inspired by nature or evolution.

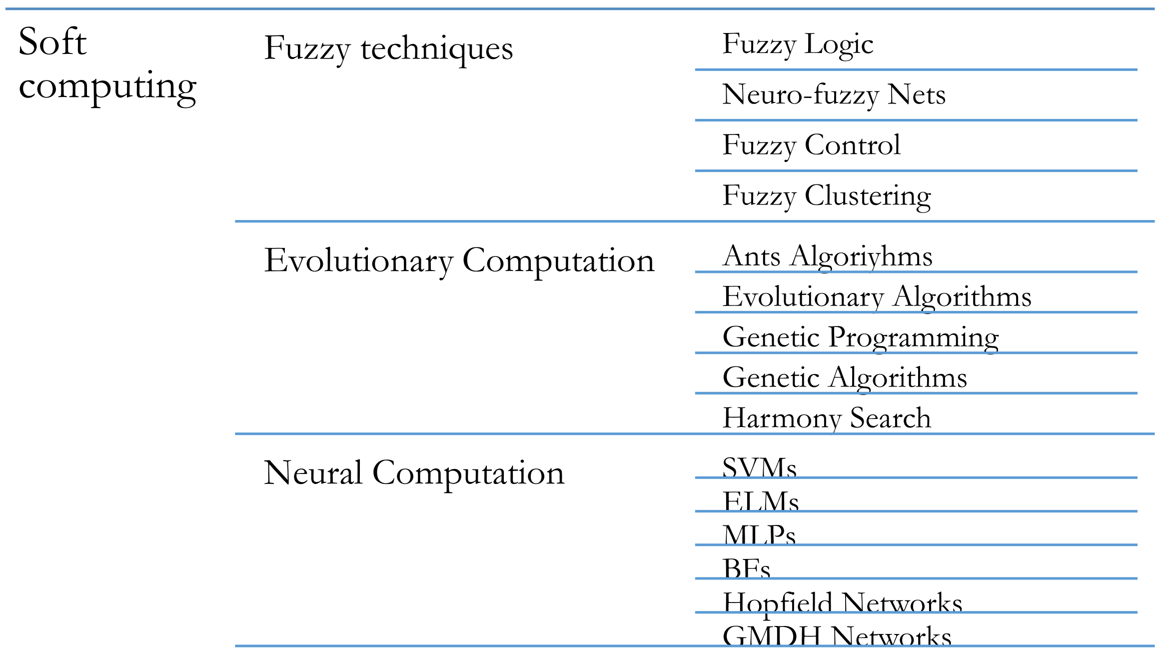

Figure 3. Soft Computing Methods.

In the field of SCM, soft computing has become an essential tool, providing strong tools to manage the dynamic, uncertain, and complicated character of current supply networks. Soft computing techniques, such neural networks, FL, GAs, and hybrid intelligent systems, can handle imprecise data, unclear information, and nonlinear relationships, in contrast to classic hard computing methods that require exact inputs and rigid models. Soft computing is very useful for assisting operational and strategic decisions throughout the SC because of these qualities. For instance, FL assists decision-makers in handling qualitative factors when choosing suppliers or controlling risks, while neural networks can precisely predict demand patterns in unpredictable market settings. Swarm intelligence and GAs are frequently employed to optimize logistics scheduling and vehicle routing, particularly when there are several constraints and goals at play. Better responsiveness and adaptability are made possible in production and inventory management by hybrid approaches that combine fuzzy systems with evolutionary algorithms. Furthermore, soft computing facilitates multi-criteria decision-making (MCDM) for choosing eco-friendly suppliers and minimizing environmental effect in the context of sustainability and green SCs. Soft computing's adaptability and learning capabilities offer a crucial advantage in preserving resilience and efficiency as SCs grow increasingly digital, circular, and global. The sections that follow examine the fundamental procedures of SCM and shows how soft computing techniques can be included into each phase to improve efficiency and flexibility. The 8 processes of SCM have been explained as demonstrated in Table 1 below.

Table 1. Supply chain management processes.

Process	Sub-processes in operations	Sub processes of strategy
Product Development and Commercialization	Describe New Items and Evaluate Fit. Create Screening and Idea Generation Procedures. Provide Rules for Participation in Cross-functional Product Development Teams. Determine Problems and Limitations with Product Rollout. Create Project Guidelines for New Products.	Examine sourcing, manufacturing, marketing, and corporate strategies. Create a Multidisciplinary Product Development Group. Establish a New Product Development Project in writing. Create and Construct Prototypes. Make or Purchase a Choice.
Manufacturing Flow Management	Use manufacturing to determine routing and velocity. Planning for Materials and Manufacturing. Implement Demand and Capacity Constraints.	Examine your sourcing, marketing, logistics, and manufacturing strategies. Establish the Level of Flexibility Needed for Manufacturing.

	Evaluate Performance.	Establish Push/Pull Limits. Determine Capabilities and Identify Manufacturing.
Customer Relationship Management	Differentiate Customers. Get the Segment/Account Management Team ready. Examine the accounts internally. Use the Accounts to Find Opportunities.	Examine the marketing and corporate strategy. Determine the Standards for Classifying Clients. Establish Standards for the Product/Service Agreement's Level of Differentiation. Create a Metrics Framework. Create Policies for Informing Customers of the Advantages of Process Improvement.
Returns Management	Get return requests. Establish routing. Get Refunds. Pick a Disposition. Consumer/Supplier Credit. Evaluate Performance and Returns.	Establish the strategy and goals for returns management. Create guidelines for avoidance, gatekeeping, and disposition. Create options for the returns network and flow. Create Credit Guidelines. Identify Secondary Markets. Create a Metrics Framework.
Demand Management	Gather Information/Data. Projection. Synchronize. Make Things More Flexible and Less Variable.	Assess Demand Management Objectives and Approach. Establish Forecasting Methods. Plan the Information Flow. Find out Synchronization Protocols. Create a system for managing emergencies.
Order Fulfilment	Create and Share an Order. Place the Order. Order of Process. Take Care of the Documentation. Complete the order.	Examine your SC structure, marketing plan, and customer service objectives. Specify the Conditions for Order Fulfillment. Assess the Logistics System. Establish an Order Fulfillment Plan. Metrics Development Framework. Fulfill the Order. Carry out post-delivery tasks and assess results.
Customer Service Management	Identify the event. Assess the circumstances and available options. Put the Solution into Practice. Track and Document.	Create a strategy for customer service. Create response protocols. Create the necessary infrastructure to put response procedures into action. Create a Metrics Framework.
Supplier Relationship Management	Set up the Supplier/Segment Management Team. Prepare the Supplier/Segment Management Team. Examine the Supplier/Supplier Segment Internally. Find Opportunities with Suppliers. Create the Communication Plan and Product/Service Agreement.	Examine your sourcing, manufacturing, marketing, and corporate strategies. Determine the Criteria for Classifying Suppliers. Establish Guidelines for the Level of Customization in the Product/Service Agreement. Create a Metrics Framework. Create Policies for Communicating Process Improvement Advantages to Suppliers. Put the Product/Service Agreement into Action. Create Supplier Cost/ProfitabilityReports and Evaluate Performance.

4 | Soft Computing Applications in SCM

4.1 | Customer Relationship Management

Organizations expecting to succeed in the highly competitive business environment of today must use customer relationship management, or CRM. Understanding consumers' requirements, preferences, and behaviors is the foundation of CRM, which helps organizations provide individualized services and increase customer satisfaction and loyalty [26] as illustrated in Figure 4. The use of soft computing approaches has become a potent tool in recent years to enhance CRM performance by handling ambiguous, imprecise, or uncertain customer data and by capturing the complexity of human behavior. Soft computing techniques allow businesses to interpret unstructured data and simulate non-linear trends in customer behavior. ANNs, for example, can be used to forecast customer behavior and segment customers, which helps with accurate marketing decision-making [27]. In contrast, FL is useful for assessing customer satisfaction levels based on qualitative indicators that are hard to measure using traditional methods, like perceived service quality or overall consumer impression. According to recent research, integrating soft computing methods into CRM systems greatly improves decision-making efficacy and operational efficiency [28]. By choosing the best communication channels for every consumer segment, GAs, for instance, can optimize marketing campaign parameters, lowering costs and raising response rates. Additionally, hybrid models like as Neuro-Fuzzy Systems have demonstrated encouraging outcomes in terms of precisely forecasting consumer behavior and enhancing retention tactics [29]. Practically speaking, businesses can include soft computing into CRM by utilizing cutting-edge data analytics platforms that facilitate AI and machine learning as well as contemporary business intelligence (BI) solutions. Robust AI-driven functionalities for customer data analysis and predictive modeling are available in top CRM platforms including SAP CRM, Salesforce, and Microsoft Dynamics 365 [30].

Figure 4. Customer Relationship Management.

4.2 | Customer Service Management

A key element of every business looking to guarantee client loyalty and happiness is customer service management, or CSM. It includes organizing, carrying out, and overseeing operations associated with offering assistance and services to clients prior to, during, and following a purchase. CSM includes a variety of techniques and frameworks intended to improve customer satisfaction through effective communication, handling of complaints, and prompt technical or logistical assistance. Intelligent and adaptable technologies are becoming more and more necessary in CSM as digital business environments and customer demands rise.

Soft computing is an effective method for handling the ambiguity and complexity present in customer service data in this case. Soft computing techniques are intended to simulate human-like reasoning in decision-making, particularly in situations where information is ambiguous, imprecise, or incomplete. These techniques can be used in CSM applications to estimate customer satisfaction levels, improve predictive classification of customer behavior, personalize support based on pattern analysis, and offer automated issue resolution solutions. FL, for instance, can assist in evaluating customer satisfaction based on non-quantitative characteristics like sentiment, tone of voice, or complaint frequency, while neural networks can be used to examine previous support complaints and forecast the most likely future problems. In call centers, GAs can also be used to optimize the distribution of human resources based on anticipated demand volumes and issue diversity. These methods are increasingly being used in customer service decision-support systems, according to recent studies. Artificial neural networks can increase the accuracy of customer behavior prediction by more than 85% [31]. In [32], it was demonstrated that FL offers a more accurate way to guarantee consumer satisfaction, especially in multichannel settings. In [33], soft computing and machine learning were used to create an intelligent recommendation system that helps customer support representatives make decisions in real time using real-time customer data.

4.3 | Product Development and Commercialization

Product development and commercialization, a crucial stage of the product lifecycle, involves transforming creative concepts into viable goods and bringing them to market in a way that benefits businesses and consumers alike. The following steps are interconnected: concept creation, idea generating, design and prototyping, testing and validation, market analysis, commercialization strategy, and integration of post-launch feedback. In today's fiercely competitive and dynamic industries, businesses need to make sure that product development is quick, economical, and focused on the needs of the client. FL, ANNs, GAs, PSO, and hybrid approaches are examples of soft computing techniques that have become effective tools for addressing complexities, uncertainties, and nonlinearities in decision-making across the product development pipeline. In the early stages of product design, soft computing is essential, particularly when customer needs and market conditions are uncertain. Customers' ambiguous language input, such as "high quality" or "affordable," can be modeled by FL and converted into quantitative design specifications. In [34], it was claimed that by matching design elements with inaccurate customer voices, fuzzy-based Quality Function Deployment (QFD) improves customer happiness. Additionally, using historical data, neural networks can forecast market trends or product performance, and GAs optimize. Soft computing techniques enhance SC coordination, pricing strategies, demand forecasting, and marketing mix optimization throughout the commercialization stage. PSO and FL together produce more accurate and adaptive demand forecasting models, which are crucial for product launches in unpredictable or seasonal markets, according to [35]. Hybrid intelligence systems, like ANN-PSO or fuzzy-GA, have also been effectively used in go-to-market strategy planning and product portfolio selection [36]. These models simulate different market conditions and stakeholder behaviors, enabling more robust decision-making.

4.4 | Returns Management

Returns Management is an essential aspect of SC and reverse logistics that addresses the management of returned products due to faults, customer discontent, or end-of-life recovery. It aims to improve customer satisfaction, reduce operational costs, and support sustainable practices. In recent years, the complexity of returns, uncertainty in quantities, and the need for faster, data-driven decisions have led to the integration of soft computing techniques. To manage the ambiguity, imprecision, and non-linearity included in returning processes, soft computing offers strong tools. Forecasting return volumes, categorizing return causes, streamlining return routes, and assessing choices like repair, refund, or disposal are all becoming more and more common uses for these strategies. For instance, PSO and evolutionary algorithms aid in the creation of the best reverse logistics networks, while FL is used to evaluate ambiguous consumer input. Hybrid soft computing models have been shown to be useful in increasing the sustainability and efficiency of returns management systems [37]. These results demonstrate how artificial intelligence and logistics are becoming more compatible, allowing for more intelligent, flexible, and economical return plans.

4.5 | Demand Management

In SC and operations management, demand management is a strategic process that forecasts, plans, and influences customer demand in order to strike the best possible balance between supply capabilities and market demands. It includes predicting future demand, influencing it with price and marketing plans, and allocating operational resources appropriately see Figure 5. Demand management systems have benefited greatly from the use of soft computing techniques in recent years, especially when it comes to managing the uncertainty, non-linearity, and imprecise data that are prevalent in real-world situations. While ANN and hybrid models increase forecasting accuracy by learning from historical and environmental data, FL, for instance, makes it possible to represent ambiguous or qualitative information, such as customer mood. Recent developments like metaheuristic-enhanced neural models and deep learning-fuzzy hybrids [38] demonstrate encouraging gains in predicting accuracy and adaptability. By enabling systems that are more adaptable, resilient, and able to learn from changing market conditions, these advancements show how soft computing improves demand management. The incorporation of soft computing into demand management will continue to enhance operational effectiveness, customer satisfaction, and competitive advantage as companies depend more and more on data-driven decision-making.

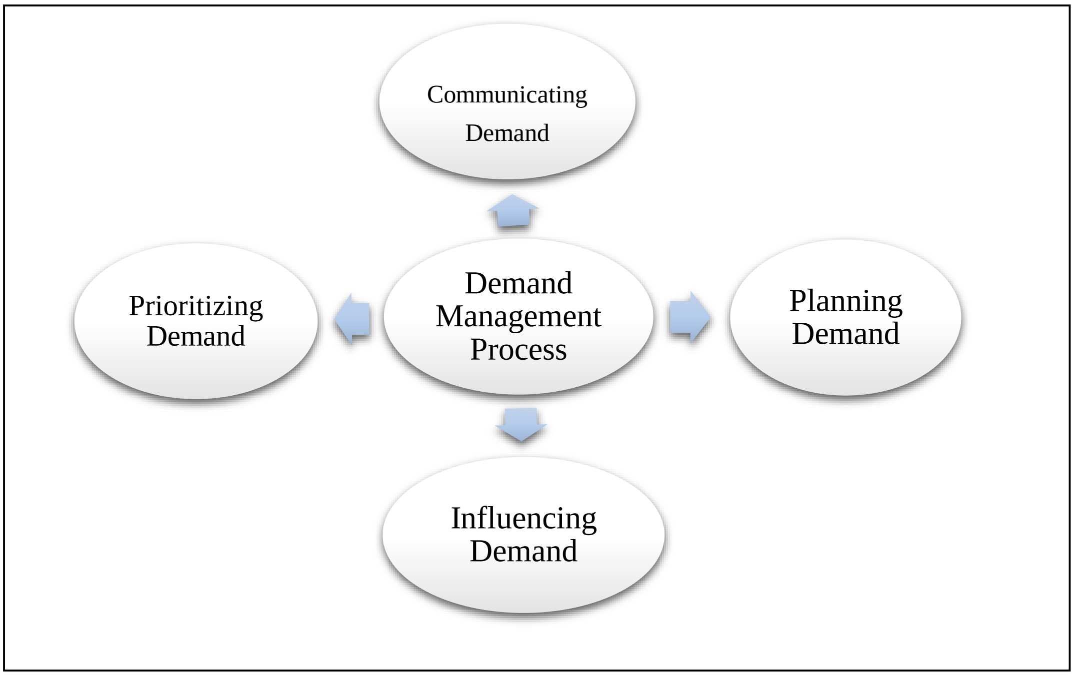

Figure 5. Process of Demand Management.

4.6 | Order Fulfilment

Order fulfillment is the comprehensive process of accurately and efficiently receiving, processing, and delivering client orders. Order receiving, inventory control, order processing, picking, packing, shipping, and after-sales support are some of the crucial phases involved. Customer happiness, SCM competitiveness, and operational efficiency all depend on efficient order fulfillment. The use of soft computing techniques has greatly improved order fulfillment systems in recent years. By maximizing inventory levels, boosting demand forecasts, and improving delivery route planning, these techniques allow for better management of the uncertainties and complexity present in SCs. For instance, evolutionary algorithms optimize delivery routes to reduce time and cost, while FL may handle imprecise data for dynamic inventory control. Proactive decision-making is made possible by machine learning models, which support predictive analytics for interruptions in demand and logistics. Thus, the use of soft computing results in order fulfillment procedures that are more intelligent, flexible, and effective.

4.7 | Manufacturing Flow Management

Manufacturing Flow Management (MFM), which concentrates on the effective flow of goods and materials through manufacturing processes, is an essential part of SC management. Effectively meeting client expectations while preserving cost-effectiveness and operational flexibility requires planning, scheduling, and flow control. The adoption of soft computing approaches, which are especially helpful for managing uncertainty, imprecision, and complicated decision-making situations typical in manufacturing contexts, has improved MFM more and more. FL is one technique that has been used to handle ambiguous data and model industrial flexibility. GAs, on the other hand, optimize machine loading and minimize system imbalance. Bayesian networks also facilitate probabilistic thinking in inventory management and production scheduling. More responsive and adaptable manufacturing systems have also been made possible by developments in artificial intelligence, such as machine learning and multi-agent systems. These technologies have been used in big data analytics and smart manufacturing scheduling in manufacturing IoT contexts, enabling real-time decision-making and increased efficiency. MFM has been successfully transformed into a more intelligent and flexible process that can better adapt to changing market demands through the integration of various soft computing techniques [39].

4.8 | Supplier Relationship Management

Building and sustaining long-term, value-driven partnerships with suppliers is the fundamental goal of supplier relationship management (SRM), a strategic approach that aims to boost innovation, lower risks, and improve organizational performance. SRM seeks to promote cooperation and alignment between suppliers and consumers rather than depending just on transactional relationships. Its activities are explained in Figure 6. FL, ANNs, GA, and MCDM techniques like AHP and TOPSIS are examples of soft computing techniques that have been widely used in recent years to enhance SRM decision-making, particularly for supplier evaluation and selection. These techniques are perfect for complicated SC systems because they efficiently handle imprecision and uncertainty in real-world data. Furthermore, SRM has been transformed by the incorporation of digital technologies like cloud computing, block chain, IoT, and artificial intelligence, which have made it possible for real-time tracking, predictive analytics, and increased transparency. In [40], the expanding significance of digital technologies and soft computing in converting SRM into a more sophisticated, data-driven procedure was emphasized. These advancements support robust and flexible SCs in addition to improving supplier performance.

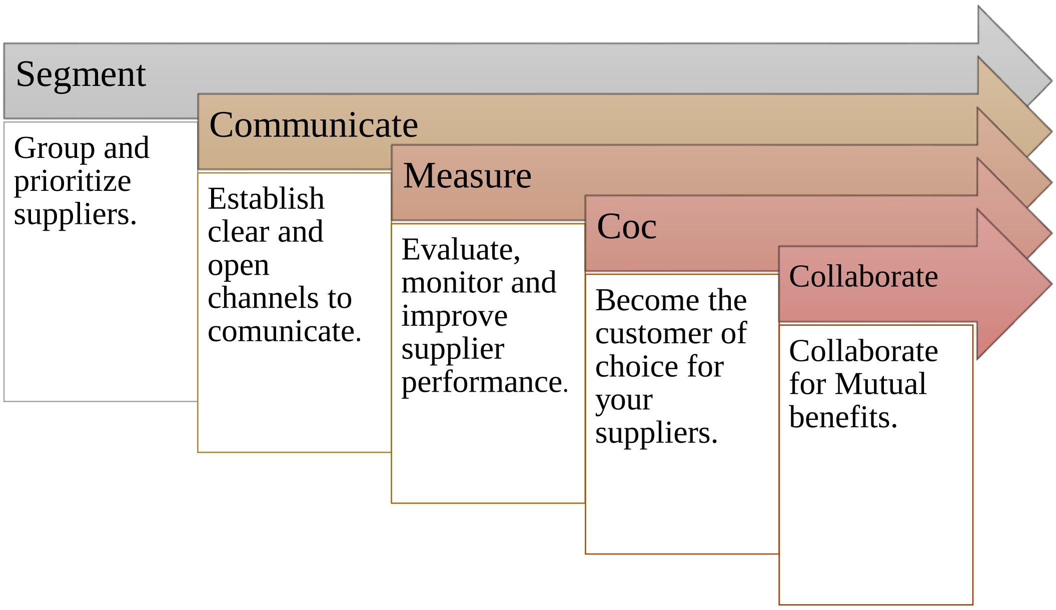

Figure 6. Supplier Relationship Management Activities.

5 | Conclusions and Future Works

The increasing complexity, unpredictability, and speed of today's SCs have been successfully addressed by the use of soft computing approaches into SCM. To address issues that conventional optimization and rule-based systems find difficult to handle, methods like FL, ANNs, GAs, PSO, and hybrid models have gained widespread use. More precise demand forecasting, adaptable inventory management, flexible production scheduling, effective transportation routing, and real-time decision-making have all been made possible by these techniques. FL, for instance, has made it possible for decision-makers to include imprecise or ambiguous data, like consumer preferences or industry trends, in operational models. Multi- distribution networks have been optimized using GAs while taking lead time, cost, and capacity limitations into account. NNs, meanwhile, have proven useful in predicting demand trends and identifying irregularities in SC data. The findings from the past ten years demonstrate that soft computing techniques increase SCs' responsiveness and resilience in addition to their operational effectiveness. Soft computing still hasn't reached its full potential, nevertheless.

There are currently some drawbacks, such as difficulties combining various soft computing techniques into a coherent framework, scalability problems when handling massive amounts of data, and difficulties adjusting models to real-time changes in extremely dynamic situations. Future studies require to concentrate on a few important topics. In order to produce more resilient and adaptable models, it is first necessary to create hybrid intelligent systems that integrate the advantages of several soft computing techniques, such as NNs and FL or EAs and reinforcement learning. Second, by integrating with technologies like block chain, Big Data analytics, and the IoT, the use of soft computing should be expanded to facilitate data-driven, real-time decision-making. SCs will become more automated, transparent, and predictive as a result. Furthermore, managing the enormous datasets that are frequently produced in global SCs requires the development of scalable and effective algorithms that can function in dispersed or cloud-based contexts. Validating these methods through case studies unique to a certain business is another crucial step that would encourage broader adoption and offer useful insights. In summary, soft computing is now a strategic enabler of modern SC transformation rather than a supplemental tool. In the age of digitalization and Industry 4.0, its agility, flexibility, and ability to learn from ambiguous and partial data make it crucial for creating SCs that are intelligent, agile, and sustainable.

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Conflicts of Interest

The authors declare that there is no conflict of interest in this research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Farhadi, A., Mahalegi, H. S. M., Firouzabad, A. P., Zamanifar, A., & Sorouri, M. (2024). Leveraging Blockchain and ANFIS for Optimal Supply Chain Management. arXiv preprint arXiv:2408.17161. https://doi.org/10.48550/arXiv.2408.17161

[2] Ceptureanu, E. G., Ferraro, G., Ceptureanu, S. I., Lazar, R., Florescu, M., & Matei, A. (2025). Impact of artificial intelligence and blockchain on supply chain resilience under influence of change management. Soft Computing, 1-9.

[3] Li, X., & Ma, H. (2020). Soft computing in smart logistics. Soft Computing, 24, 6193-6195. https://doi.org/10.1007/s00500-020-04836-5

[4] Daios, A., Kladovasilakis, N., Kelemis, A., & Kostavelis, I. (2025). AI Applications in Supply Chain Management: A Survey.

[5] LeMay, S., Helms, M. M., Kimball, B., & McMahon, D. (2017). Supply chain management: the elusive concept and definition. The International Journal of Logistics Management, 28(4), 1425-1453.

[6] Zhao, J., Ji, M., & Feng, B. (2020). Smarter supply chain: a literature review and practices. Journal of Data, Information and Management, 2(2), 95-110.

[7] Wang, M., Miao, L., & Zhang, C. (2021). A branch-and-price algorithm for a green location routing problem with multi-type charging infrastructure. Transportation Research Part E: Logistics and Transportation Review, 156, 102529. https://doi.org/10.1016/j.tre.2021.102529

[8] Wen, X., Choi, T. M., & Chung, S. H. (2019). Fashion retail supply chain management: A review of operational models. International Journal of Production Economics, 207, 34-55. https://doi.org/10.1016/j.ijpe.2018.10.012

[9] Jung, J., Yu, J., Seo, Y., & Ko, E. (2021). Consumer experiences of virtual reality: Insights from VR luxury brand fashion shows. Journal of Business Research, 130, 517-524. https://doi.org/10.1016/j.jbusres.2019.10.038

[10] Chekurov, S., Metsä-Kortelainen, S., Salmi, M., Roda, I., & Jussila, A. (2018). The perceived value of additively manufactured digital spare parts in industry: An empirical investigation. International Journal of Production Economics, 205, 87-97. https://doi.org/10.1016/j.ijpe.2018.09.008

[11] Robinson, S., & Eilert, M. (2018). The role of message specificity in corporate social responsibility communication. Journal of Business Research, 90, 260-268.

[12] Kale, V. (2019). Digital transformation of enterprise architecture. CRC Press.

[13] Abiodun, O. I., Jantan, A., Omolara, A. E., Dada, K. V., Mohamed, N. A., & Arshad, H. (2018). State-of-the-art in artificial neural network applications: A survey. Heliyon, 4(11).

[14] Abdolrasol, M. G., Hussain, S. S., Ustun, T. S., Sarker, M. R., Hannan, M. A., Mohamed, R., ... & Milad, A. (2021). Artificial neural networks based optimization techniques: A review. Electronics, 10(21), 2689. https://doi.org/10.3390/electronics10212689

[15] Alrasheedi, A., & Almalaq, A. (2022). Hybrid deep learning applied on Saudi smart grids for short-term load forecasting. Mathematics, 10(15), 2666. https://doi.org/10.3390/math10152666

[16] Ilbahar, E., Cebi, S., & Kahraman, C. (2020). Assessment of renewable energy alternatives with pythagorean fuzzy WASPAS method: a case study of Turkey. In Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making: Proceedings of the INFUS 2019 Conference, Istanbul, Turkey, July 23-25, 2019 (pp. 888-895). Springer International Publishing.

[17] Wang, Y., Liu, H., Jia, W., Guan, S., Liu, X., & Duan, X. (2021). Deep fuzzy rule-based classification system with improved Wang–Mendel method. IEEE Transactions on Fuzzy Systems, 30(8), 2957-2970.

[18] Zhang, H., Wu, C., Zhang, Z., Zhu, Y., Lin, H., Zhang, Z., ... & Smola, A. (2022). Resnest: Split-attention networks. In Proceedings of the IEEE/CVF conference on computer vision and pattern recognition (pp. 2736-2746).

[19] Ng, M., Gakidou, E., Lo, J., Abate, Y. H., Abbafati, C., Abbas, N., ... & Azargoonjahromi, A. (2025). Global, regional, and national prevalence of adult overweight and obesity, 1990–2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. The Lancet, 405(10481), 813-838.

[20] Murhekar, M. V., Bhatnagar, T., Thangaraj, J. W. V., Saravanakumar, V., Kumar, M. S., Selvaraju, S., ... & Vinod, A. (2021). SARS-CoV-2 seroprevalence among the general population and healthcare workers in India, December 2020–January 2021. International Journal of Infectious Diseases, 108, 145-155.

[21] Xue, Li, Xiaojie Liu, Shijun Lu, Guangyan Cheng, Yuanchao Hu, Junguo Liu, Zhengxia Dou, Shengkui Cheng, and Gang Liu. "China's food loss and waste embodies increasing environmental impacts." Nature Food 2, no. 7 (2021): 519-528.

[22] Deb, P., Kiem, A. S., & Willgoose, G. (2019). A linked surface water-groundwater modelling approach to more realistically simulate rainfall-runoff non-stationarity in semi-arid regions. Journal of Hydrology, 575, 273-291. https://doi.org/10.1016/j.jhydrol.2019.05.039

[23] Sarraj, A., Hassan, A. E., Abraham, M. G., Ortega-Gutierrez, S., Kasner, S. E., Hussain, M. S., ... & Albers, G. W. (2023). Trial of endovascular thrombectomy for large ischemic strokes. New England Journal of Medicine, 388(14), 1259-1271.

[24] Yan, L., Sha, L., Zhao, L., Li, Y., Martinez-Maldonado, R., Chen, G., ... & Gašević, D. (2024). Practical and ethical challenges of large language models in education: A systematic scoping review. British Journal of Educational Technology, 55(1), 90-112.

[25] Zhao, X., Ma, X., Chen, B., Shang, Y., & Song, M. (2022). Challenges toward carbon neutrality in China: Strategies and countermeasures. Resources, Conservation and Recycling, 176, 105959.

[26] Buttle, F., & Maklan, S. (2019). Customer relationship management: concepts and technologies. Routledge.

[27] Chatterjee, S., & Chaudhuri, R. (2023). Customer relationship management in the digital era of artificial intelligence. In Digital Transformation and Industry 4.0 for Sustainable Supply Chain Performance (pp. 175-190). Cham: Springer International Publishing.

[28] Patel, S. Y., McCoy, R. G., Barnett, M. L., Shah, N. D., & Mehrotra, A. (2021). Diabetes care and glycemic control during the COVID-19 pandemic in the United States. JAMA internal medicine, 181(10), 1412-1414.

[29] Gončarovs, P. (2017). Data analytics in crm processes: A literature review. Information Technology and Management Science, 20(1), 103-108.

[30] Gartner, J., Maresch, D., & Tierney, R. (2024). The key to scaling in the digital era: Simultaneous automation, individualization and interdisciplinarity. Journal of Small Business Management, 62(2), 628-655.

[31] Syu, J. H., Lin, J. C. W., Srivastava, G., & Yu, K. (2023). A comprehensive survey on artificial intelligence empowered edge computing on consumer electronics. IEEE Transactions on Consumer Electronics, 69(4), 1023-1034.

[32] Sohaib, O., Arman, A., Begum, V., & Arshi, T. (2024). Applying fuzzy logic to balanced scorecard for the performance evaluation of government e-services. Journal of Science and Technology Policy Management.

[33] Manoharan, G., Durai, S., Rajesh, G. A., & Ashtikar, S. P. (2023). A study on the application of expert systems as a support system for business decisions: A literature review. Artificial Intelligence and Knowledge Processing, 279-289.

[34] Singh, R., Pathak, V. K., Kumar, R., Dikshit, M., Aherwar, A., Singh, V., & Singh, T. (2024). A historical review and analysis on MOORA and its fuzzy extensions for different applications. Heliyon, 10(3).

[35] Azeem, F., Ahmad, A., Gondal, T. M., Arshad, J., Rehman, A. U., Eldin, E. M. T., ... & Hamam, H. (2022). Load management and optimal sizing of special-purpose microgrids using two stage PSO-fuzzy based hybrid approach. Energies, 15(17), 6465.

[36] Lu, Y., Chen, S., & Pan, X. (2025). A Hybrid Heuristic Algorithm for Optimizing the Optimal Landing Time Window Problem in Intelligent Air Transportation Systems. IEEE Transactions on Intelligent Transportation Systems.

[37] Zhang, X., Li, Z., Wang, Y., & Yan, W. (2021). An integrated multicriteria decision-making approach for collection modes selection in remanufacturing reverse logistics. Processes, 9(4), 631.

[38] Bui, T. A. (2024). Connection between Flatness and Generalization. reading.

[39] Bi, Z., Jin, Y., Maropoulos, P., Zhang, W. J., & Wang, L. (2023). Internet of things (IoT) and big data analytics (BDA) for digital manufacturing (DM). International Journal of Production Research, 61(12), 4004-4021.

[40] El-Hawy, M. A. H. (2024). Shadowed AHP for multi-criteria supplier selection. arXiv preprint arXiv:2409.09082. https://doi.org/10.48550/arXiv.2409.09082