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Review Article

Exploring Artificial Intelligence Integration in Supply Chain Management: A Review

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Abstract - *There is exponential growth in Information and communication technology, and its adoption is spreading rapidly in supply chain management (SCM), which is critical in optimizing supply chain network flow decisions. As companies seek to improve supply chain effectiveness through increased integration, ICT can be considered a key enabler for supply chain management by supporting information-sharing; hence, organizations realise competitiveness, lower inventory and supply chain costs, improve service level, and reduce risks. Today organizations are adopting Artificial Intelligence. This paper seeks to identify the contributions of artificial intelligence (AI) to supply chain management (SCM) through a systematic review of the existing literature. We, therefore, propose a maturity model that can support in-depth empirical studies seeking to explore how Artificial Intelligence influences integration in supply chain fields, including logistics, marketing, supply chain and production. This paper provides insights through systematic analysis and synthesis.*

Keywords - *Artificial Intelligence, Information and Communication Technology, Maturity Model, Supply Chain Management.*

1. Introduction

There is rapid development in information and communications technology (ICT) in logistics and supply chain management. It has provided new ways to store, process, distribute and exchange information within companies and with customers and suppliers in the supply chain. Therefore, ICT can be said to be an enabler for information sharing, which corporations in the supply chain can use to eradicate the so-called bullwhip effect [1]. Globally, most organizations have been trying to digitise their processes for the last two decades, and new technologies such as Industry 4.0 have emerged as a business buzzword [2]. On the other hand, the intelligence of computing devices has been leveraged. Of such technologies is Artificial Intelligence (AI).

AI has long been predicted as one of the protuberant technologies capable of allowing communication among devices and machines ([3][4][5]). Since the supply chain involves a series of complex tasks, AI can simplify processes by solving problems at higher levels of speed and accuracy while at the same time managing large volumes of data [6]. AI is not new, but its potential for huge applications, including supply chain management, has only been recognized more recently [7]. Applying AI in the supply chain can facilitate smart and agile decision-making to anticipate problems. It implies that a well-defined integration strategy of AI may help organizations in enhancing the quality of service and in savouring customers through on-time and undamaged deliveries ([8][9]). Besides, intelligent technologies like AI can aid companies in supporting their supply chain flexibility.

Organizations today have appreciated that it is not conceivable to achieve effective and efficient supply chains without a sound, robust and well-integrated enterprise-wide information system [10]. Despite the many capabilities of ICTs such as AI, there is equally emergence of the serious threat of cyber-crime through computer facilitation or computer as a target [11]. With the perceptibility capability of AI-based technologies, one can perceive how the entire chain can be affected by a particular phenomenon over a certain period [12]. This paper seeks to identify the contributions of artificial intelligence (AI) to supply chain management (SCM) through a systematic review of the existing literature. We, therefore, propose a maturity model that can support in-depth empirical studies seeking to explore how Artificial Intelligence influences integration in supply chain fields such as logistics, marketing, supply chain and production. This paper provides insights through systematic analysis and synthesis

2. Materials and Methods

This study adopted an evidence-informed, systematic literature review approach. This approach enabled us to overcome the recognized weaknesses of a narrative review ([13][14]). The authors adopted the five-step process outlined by Denyer and Tanfield [15] as depicted in Fig. 1, including a pilot search in the first stage to advance a deeper understanding of the existing literature, develop the criteria for literature selection and derive the research question and the subsequent steps.

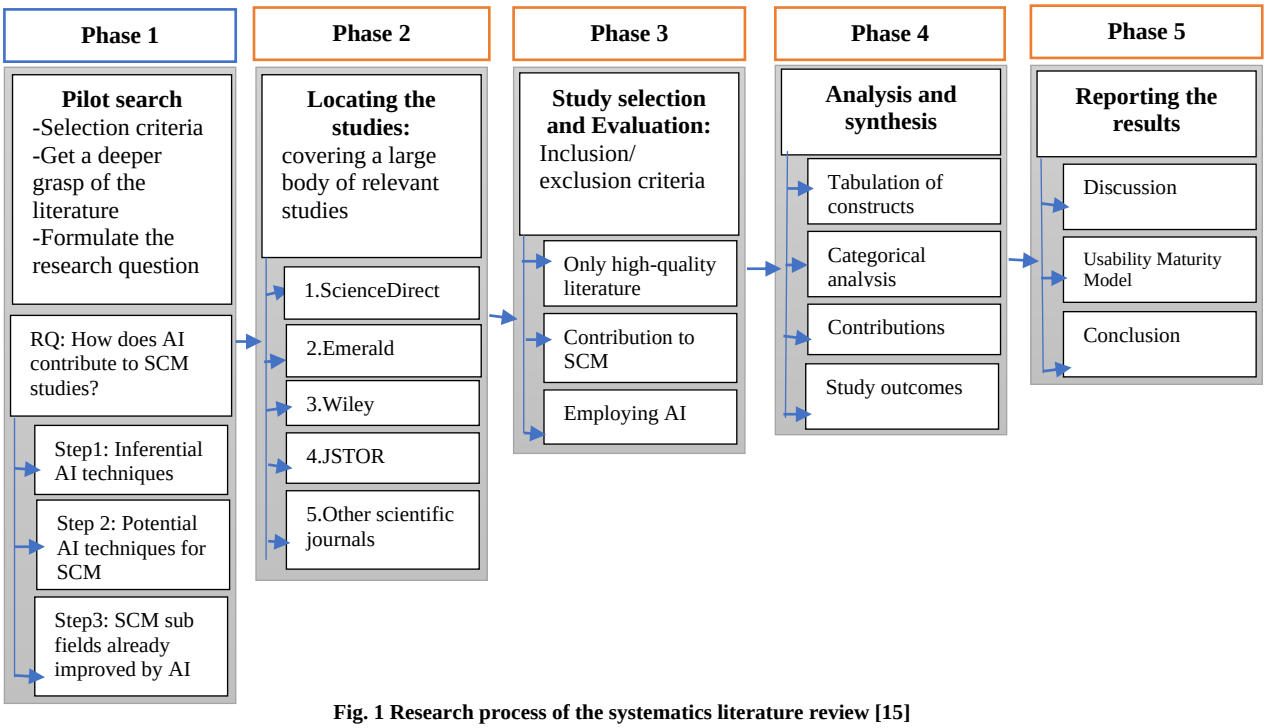

Fig. 1 Research process of the systematics literature review [15]

Four sub-research questions (SRQs) were formulated as part of the design (SRQ 1): Identify the subfields and tasks in SCM that have already been improved using AI. (SRQ 2) Identify the potential AI techniques that can be employed in SCM research. (SRQ 3) Identify the subfields and tasks that have high potential to be improved by AI. (SRQ 4) Propose an AI maturity model for assessing the integration of AI in SCM. SRQs 1 and 3 aim to analyze the prevailing literature and provide a deep understanding of the present state of knowledge for both researchers and practitioners. SRQs 2 and 4 drive to identify potential gaps and opportunities for research and practice improvement and devise a recommendation for future research.

3. Results and Discussion

3.1. Artificial Intelligence Techniques in SCM

AI uses data science philosophies to handle the volume, velocity, variety, veracity, value, variability, and data visualisation for critical insights [9]. Several AI techniques have received minimal or no attention from SCM scholars, notwithstanding their suitability for inclusion in imminent SCM studies. Studies by [16] and [17] introduce a group of AI techniques and their application. More comprehensively, Toorajipour [8] presents a thorough catalogue of AI techniques as a reference work available for different purposes.

One of the notable AI technologies is natural language processing (NLP): which entails creating computer programs that can understand human (natural) language as input [18]. Applications of NLP range from low-level tasks such as speech to words to a high level such as providing specific answers to questions [19]. In other words, NLP is the use of computers to understand and process human language in text or speech). It is a very important concept in the SCM field. NLP interfaces allow computers to interact with humans using natural language, such as query databases [18]. This quality attribute permits NLP to be a significant facilitator in SCM, mainly due to its ability to enhance and simplify human-machine interactions.

Text mining is an exemplification of NLP at its most practical: discovering information in prose of various types [19] to support production, manufacturing and logistics. Processes of that nature play an integral role in accelerating industrial procedures and advancing data generation and collection due to simplified exchanges between beings and machines. The advancement of chatting robots or “chatbots” is increasingly being evidenced in today’s world. Many social networking sites (SNS) and websites incorporate Chatbots, which defines a new paradigm in computer-based marketing communication [20]. NLP techniques in the form of chatbots have great potential in promotion campaigns, online advertisement, brand management, customer relationship management and data assemblage. Chatbots have been leveraged as a means for improved relations with customers [21], and big firms such as Safaricom and Facebook messenger use chatbots as a means to accelerate and facilitate their customer service processes ([20][22]).

Using Neural networks as a form of AI technique in SCM has become a common phenomenon. Gligor et al. [23] propose an Artificial Neural Network (ANN)-based solution for foretelling the electricity production of a photovoltaic power plant. On the other hand, [24] focus on variant models, including a feedforward neural network model and a Gamma classifier for forecasting in the time series context of petroleum engineering. Küfner, Uhlemann, and Ziegler [25] note that production systems utilize distributed data analysis for dispersed data reduction and information extraction; these models could be used to perceive production faults and reduces machine maintenance costs. [26] propose an AI forecasting mechanism modelled using ANNs and adaptive network-based fuzzy inference system techniques to manage the fuzzy demand with incomplete information. Amirkolaii et al. [27] present a survey on forecasting methods used in supply chains to select the best performing AI methods.

Another variant of the AI technique is Fuzzy logic. [28] and [29] address manufacturing systems using fuzzy logic FL) and Gaussian models. [30] approach manufacturing decision support using case-based reasoning (CBR) and rule-based reasoning (RBR). On the other hand, Bala [31] develops an AI forecasting model for retailers based on customer segmentation to improve inventory performance. Another important area of AI is robotics. Robots are a system of rigid bodies or links connected by joints. [32] names robot dynamics and robot programming as specific AI techniques. These technologies have been in use for a long time, and now and then, new inventions are advanced. Robots can be used in SCM for faster and error-free customer service deliveries. From the Literature review, therefore, AI techniques can be summarized as shown in Table 1.

Table 1. AI techniques in SCM Areas

Category	Supply Chain	Marketing	Logistics	Production
Technique	Artificial neural networks Agent-based /multi-agent-based systems Bayesian networks Swarm intelligence Stochastic simulation	Artificial neural networks Genetic algorithms Agent-based /multi-agent-based systems Hill climbing Tree-based model	Agent-based /multi-agent-based systems Robot programming Heuristics Artificial neural networks Fuzzy logic	Artificial neural networks Genetic algorithm Decision trees Expert systems Swarm intelligence Rule-based reasoning

3.2. Supply Chain Management Areas

Supply chain management may be viewed as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain to improve the long-term performance of the individual companies and the supply chain as a whole [33]. Supply chain management is constantly evolving. The corporate world is transitioning from one paradigm to the next. In the corporate sector, supply chain 4.0 is the most recent trend. [34] informed about the impact of SCM on the success of an organization. Today, SCM practices have heavily leveraged on ICTs, including Artificial Intelligence.

In SCM, AI integration range from sales forecasting, marketing Decision Support Systems, pricing and customer segmentation to production forecasting, supplier selection, demand management and consumption forecasting. Therefore, AI enables computerized compliance that results in lower costs and efficient functioning of a value chain network [35].

3.3. AI integration in Supply Chain Management

Supply chain management may be viewed as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company. AI also significantly enhances the predictive capabilities required for demand forecasting in today's dynamic business environment. AI can be very efficient in the engagement of customers as interactions can be personalized by AI-driven bots, which can aid in tracking the delivery status of an item and are further supported by echo users assisted by a customer support team [22]. The use of AI may help in tracking the performance of warehouses in terms of demand and shelf life. It could be done by robustly examining stock levels and aligning associated activities accordingly [36].

AI-based inventions can promote real-time coordination and collaboration to enable supply chains to have improved visibility ([9] [37]). The demand patterns can be determined based on dynamic capabilities, margins, and the location from which a company is operating [38]. The concept of network planning and mapping in the supply chain is so important that AI can advance. The AI technologies can assist the supply chain regarding production, routes, and other linking nodes [39]. Collaboration between contractors and suppliers can be improved in shaping the supply chain in unprecedented times without forgetting consumers [40].

AI can potentially influence real-time pricing (RTP) as a major component in SCM. RTP is an important demand-side management factor regulating the load curve to realize peak load shifting. As stated in the literature [17], it has the potential to be covered on a deeper level using AI. There are lots of studies, for example, on RTP in China ([41] [35]).

AI facilitates supply chains in environmental scanning, demand, supply, process and control [42] and offers the two-dimensional view in Figure 1. AI-based innovation has the potential to fast-track the decision process by recognizing, experimenting, and examining novel solutions ([9] [39]). Based on the above literature review, we can also consider AI a key enabler to facilitate smart and agile decision-making in the supply chain to anticipate problems, reduce costs, and promote a value chain network [35]. It facilitates quality of service and in delighting customers through on-time and undamaged deliveries ([43] [9] [22]).

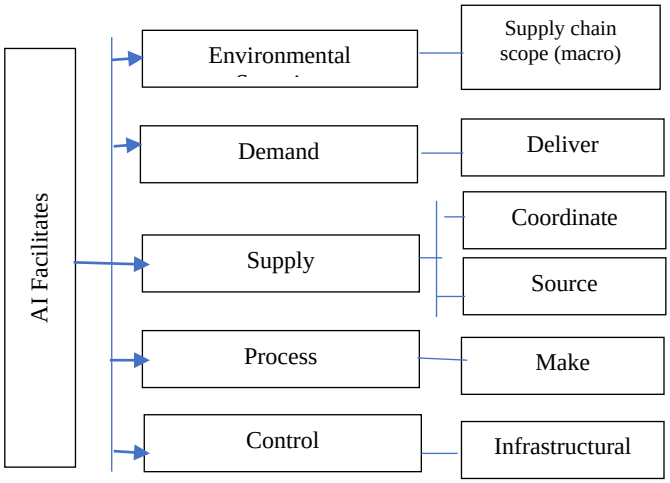

Fig. 2 AI impact on different dimensions of SCM [42]

4. AI Integration Maturity Model (AIIMM)

Effective supply chains are critical to delivering justifiable access to safe, quality, affordable supplies and services. The performance of supply chains can be immensely improved by adopting appropriate ICT technologies. Based on the literature review on supply chain integration and the impact of artificial intelligence, it is important to evaluate the extent to which these technologies are implemented in organizations. We propose a theoretical model to measure the maturity of the Integration of AI in SCM. The purpose is to provide further insights into the complex relationship between AI and the integration of supply chain control. The proposed model can be used as a starting point for empirical investigations within the field, defining the scope of the study or as an analytical framework.

Maturity models have been proposed as a tool that could help people assess the current effectiveness of technology integration for overall performance improvement. Firms should consider the continued use of the maturity model, either for monitoring present maturity levels or continuing to advance toward new goals in maturity [44]. The maturity of SCM is derived from the understanding that the process has a life cycle or clearly defined stages that can be measured and controlled. Assessment of maturity of processes involves five stages ([45] [44]):

Level 1 Ad hoc: At this level, processes are usually undocumented and in a state of change. Order, time and results are different in the repetition process and require supervision.

Level 2 Repeatable: The process is repeatable; there is no strict process specification without any product owner definition.

Level 3 Controlled: Define, record, establish and implement standard specifications; improve over time.

Level 4 Managed: Management uses process metrics and control methods to align the process with business goals and customer needs.

Level 5 Optimized: The focus of the process is to improve through innovative changes

AI can be defined as an industry 4.0 technology that is capable of revolutionizing many businesses and fields ([46] [47]). As such, almost all the fields of SCM and its subfields are prone to be influenced by AI. The integration of AI can equally be viewed as a process that has a start and matures with time; hence not instantaneous. Effective SCM practices help organizations achieve a competitive advantage over competitors, leading to customer delight as the customers get the products & services per their expectations. We propose an AI integration maturity model, as shown in Fig.2

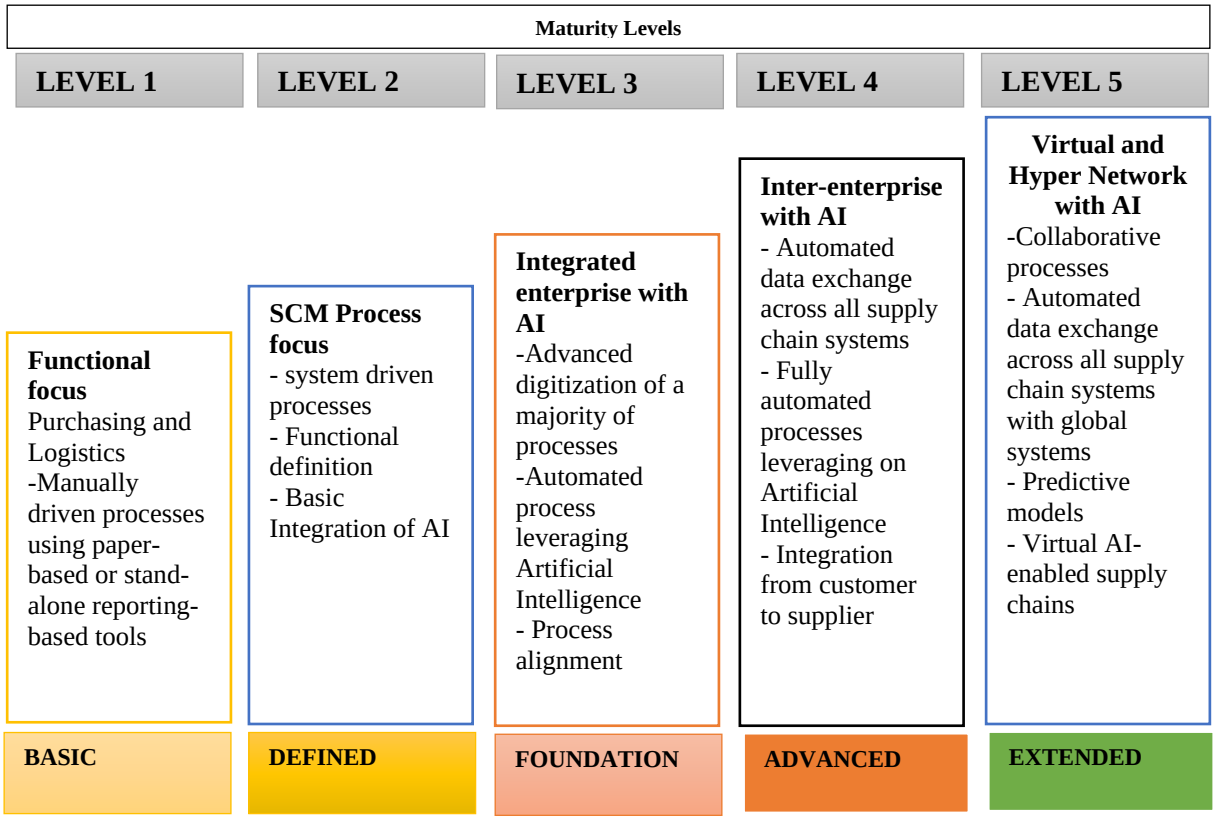

Fig. 3 AI Integration Maturity Model (AIIMM) in Supply Chain Management

5. Conclusion

This paper presents a detailed review of literature on the impact of ICT with a specific focus on Artificial Intelligence integration in supply chain Management. Recent breakthroughs in computing power have enabled the growth and complexity of AI applications. Building on this further, the current research aims to clarify how AI contributes to SCM studies based on a systematic review of the literature. We propose a maturity model. It is developed based on the literature on supply chain integration and the impact of AI from a supply chain perspective. This research further insights into the complex relationship between AI and supply chain integration. As the model is based on only a limited selection of a considerable amount of literature, it can be further developed from a more comprehensive literature review. It can also be further developed from experiential testing based on case studies.

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