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Green Supply Chain Management based on Artificial Intelligence of Everything

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Abstract

Aim/purpose – This research aims to design an analytical framework to investigate the dimensions, factors, and key indicators affecting the green supply chain based on the innovative technology of Artificial Intelligence of Everything (AIoE). Understanding the cause-and-effect relationships of all actors in this smart and sustainable system is also one of the critical goals of this research. Also, examining the key features of AIoE technology as a new hybrid technology is one of this research's most essential features.

Design/methodology/approach – This research has tried to extract and refine the most critical parameters affecting the green supply chain based on technology by reviewing the literature and examining the opinions of active experts in the field of study. Then, by using the focus group, it has been tried to provide an analytical framework to express the cause-and-effect relationships of all actors active in this system by examining the basic features of AIoE. Finally, this framework was validated and approved using experts' opinions and the focus group, emphasizing integrity, comprehensiveness, and effectiveness.

Findings – This research identified the dimensions, components, and indicators affecting the smart, green, and sustainable supply chain based on Artificial Intelligence (AI). It also presented an analytical framework that shows the cause-and-effect relationships of all active actors in this system.

Research implications/limitations – This research simultaneously offers significant insights into implementing intelligent and sustainable process-oriented systems. However, it is important to note the limitations. One of the most significant challenges in presenting the framework was finding experts with sufficient awareness, knowledge, and experience and participants to analyze cause-and-effect relationships.

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Originality/value/contribution – This research provides a practical analysis of AIoE technology for the first time. The results strongly support the argument that hybrid AIoE technology can tremendously impact the sustainability and greenness of supply chain processes.

Keywords: green supply chain, sustainable supply chain, Artificial Intelligence of Everything (AIoE), AIoE-based supply chain.

JEL Codes: O32.

1. Introduction

Green Supply Chain Management (GSCM) involves integrating environmentally friendly practices into the traditional supply chain to achieve sustainable development (Nozari et al., 2021a). To increase the organization's social responsibility, it is necessary to change the traditional supply chain management method. Going green and trying to achieve the goals of a sustainable supply chain is the most critical solution in this field (Nazir et al., 2024). Many businesses have become aware of the importance of this integration to create a sustainable business strategy. They are looking for solutions and guidance on implementing a sustainable supply chain. Also, a sustainable supply chain is not exclusively about green issues but about creating efficiencies and cost containment. As organizations seek to define management to reduce their company's environmental footprint, supply chains have become their primary area of focus. However, it can be said that being green is one of the most critical components of sustainability. Therefore, special attention should be paid to it in supply chain processes (Nozari et al., 2021b).

In today's era, transformative technologies are developing more and more. These technologies have tremendous effects on business processes. So, businesses cannot create a competitive advantage without the presence and use of digital and smart technologies (Vaseei et al., 2024). Using these technologies, business processes, including supply chains, can be sustainable in all their elements. For example, using Internet of Things (IoT) technology, large amounts of data can be extracted and refined, which was impossible in the past. Data that is unstructured in many cases, and in many cases, other powerful technologies must be used to analyze them. Artificial Intelligence (AI) with the capability of learning analysis allows businesses to analyze big data that was impossible for them to analyze in the past (Nahr et al., 2021). Blockchain technology also provides data storage with decentralized management. This technology can guaran-

tee the security and accuracy of data in many cases. Therefore, it can be observed that these technologies in the new era, by creating the ability to monitor and analyze in real-time, can ensure the stability of intelligent supply chain systems in all its dimensions from procurement, production, repair, and Ensure maintenance, distribution, marketing, and sales (Nozari et al., 2019).

Combining these technologies can provide multiple capabilities and power to the supply chain processes. Therefore, it has tried to achieve new technologies with different capabilities in recent years by optimally combining them. Artificial Intelligence of Everything (AIoE) is a technology that involves evaluating and analyzing all people and processes in addition to objects (Nozari, 2024a). By using this technology, timely distribution can be guaranteed. Production energy can be optimized, which is a critical step in the direction of the green development of the supply chain. Of course, it should be noted that due to the importance of this concept, the examination of the green supply chain has received attention in many types of research. Also, in many researches, the role of technologies in the sustainability of the supply chain has been considered. However, due to the development of technologies in the present era and the change of industrial generations, the role of using combined technologies simultaneously in developing green and sustainable supply chains has not been analyzed. Furthermore, in this research, the concept of AIoE and its effects on the supply chain's greenness has been investigated for the first time. For this reason, this research has tried to examine the dimensions, features, opportunities, and challenges created for the green and smart supply chain powered by AIoE. Moreover, the cause-and-effect relationships of all actors are presented in a conceptual framework. Understanding this framework can provide deep insight into implementing green and smart systems, emphasizing this powerful hybrid technology.

The second part of this research presents the theoretical foundations. This section includes sub-sections on green and smart supply chains, the Internet of Everything (IoE), supply chain management, and AIoE. The third part presents the green supply chain framework based on AIoE, and finally, the fifth part presents the conclusion.

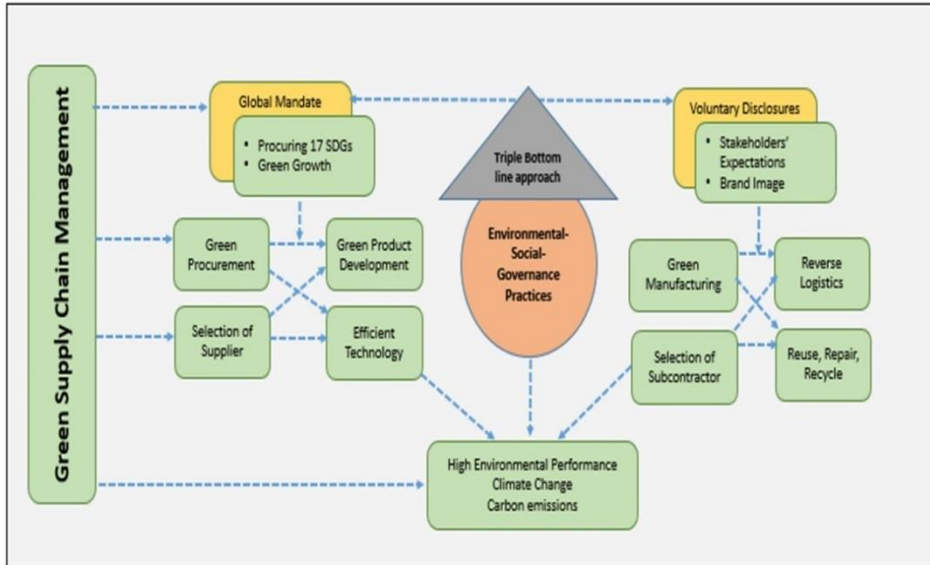
2. Theoretical foundations

This section examines concepts related to the green supply chain, emphasizing related technologies.

2.1. Green and smart supply chain

GSCM is an approach that integrates environmentally friendly methods into traditional supply chain management (Nozari et al., 2021c). In fact, GSCM integrates environmental and financial practices in the complete life cycle of the supply chain, from product design and development to material selection (raw material extraction or agricultural production), production, packaging, transportation, warehousing, distribution, consumption, to help organizations reduce their carbon footprint (Rashid et al., 2024). Unlike common considerations of supply chain administration, which center on the showcase and money-related dissemination, the green supply chain field considers social and natural criteria for green execution (Trujillo-Gallego & Sarache, 2021). Within the entire green supply chain, conventional operational forms are set up, such as fabricating and acquiring connections with accomplices in economical ways. When companies look at green hones in supply chain administration, they can arrange their operations administration to attain green execution objectives and create green supply chain administration frameworks. A smart supply chain consists of a configuration of three different hierarchical layers: digital transformation strategy, core digital technologies, and front-end technologies, and each of them can contribute to increasing green performance (Ghahremani-Nahr et al., 2020).

The digital transformation strategy in the new era can create new business models that provide a new green and sustainable perspective for companies to use the data generated for strategic positioning as a green and environmentally friendly operation in the market (Mahajan et al., 2024). Moreover, in addition to digital strategy, underlying technologies are crucial for green and sustainable performance as advanced technologies, such as the IoT, cloud, big data, and AI, facilitate the flow and management of companies' data. Various studies show that tools such as blockchain or cloud computing systems can improve transactions and monitoring of green practices, leading to better performance (Nozari et al., 2024b). Although the shrewd supply chain plays a critical part in green execution, the degree of this maintainability also depends on the setup of the green supply chain. Companies ought to structure their organizational objectives so that they are concordant with their natural objectives (Ghahremani-Nahr et al., 2020). Consequently, concurring with the arrangement approach, the finest comes about in green execution that cannot be accomplished in a supply chain utilizing advanced methodologies and advances alone. It should also be adjusted between outside exercises (green relations) and inside exercises (green operations). A conceptual model for smart GSCM is shown in Figure 1.

Figure 1. The conceptual model for smart Green Supply Chain Management

Source: Saini et al. (2023, p. 11).

2.2. Internet of Everything and supply chain management

Connecting things to the Internet and adding “Sensors” to them adds a level of digital intelligence to them. This intelligence allows objects to interact with other objects using real-time data without human intervention. The data that sensors collect depends on the type of device and its function. Devices select primary data to perform a specific action to help them make decisions. The goal of the IoT is to make communication and interaction between devices connected to the network easier by establishing a connection between sensors and devices with the Internet. However, users can view and control the equipment. The IoT is a layered architecture consisting of various devices and objects that can communicate with each other using what is called machine-to-machine communication. The architecture of this ecosystem creates the ability to transfer data in real time with minimal human intervention. Each layer in this ecosystem has a defined responsibility (Franchina et al., 2021).

Shrewd coordination frameworks are built on IoT stages and can consequently control and analyze vast amounts of information. Meanwhile, within the conventional mode, checking things and entering information were regularly done manually (Hasan et al., 2024). This capacity to gather information at the correct time makes a difference for businesses in replying to occasions and demands within the shortest possible time and accurately distinguishing the occasion's why, how, and when. However, utilizing these devices within the Web of Things generates an expansive sum of information, which needs broad survey and investigation. Huge information analytics instruments have the capacity to handle huge volumes of information produced by IoT gadgets. IoT totals information collected from different sensors, and huge information analytics devices can utilize this data to store and create experiences (Kumar et al., 2024).

AI's ability to analyze massive amounts of data, understand relationships, provide visibility into operations, and support better decision-making makes AI a potential game-changer (Belhadi et al., 2024). However, with all these descriptions, companies should take organized steps towards fully exploiting AI and not just settle for using a part of it. One of the most important applications of AI is analyzing big data and optimizing all kinds of transformational and distribution processes in the supply chain, which can contribute to the supply chain's greenness (Singh et al., 2024).

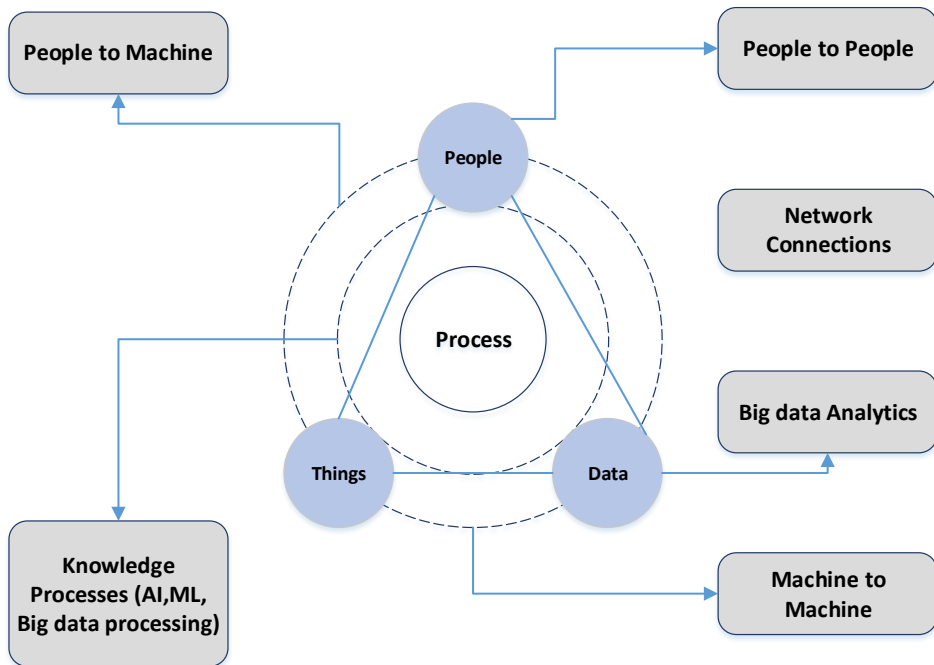
Today, the concept of the IoT has become much broader. It no longer involves just connecting things. Instead, it encompasses everything. So, in the new era, this concept has been renamed the Internet of Everything or IoE. Technically, IoE refers to the billions of devices and consumer products connected to the Internet under a smart network and can develop digital configurations. IoE is an intelligent set of connections between people, processing systems, data, and objects that can quickly move around our world (Nozari et al., 2021b). In such a network, billions of devices, such as sensors, are used to measure the environment, and their data are available through public or private networks. The four main pillars of the IoE are:

- People: Today, most people are connected through social networks on the web.
- Objects: Things here mean physical objects connected to the Internet and each other as a whole. These devices understand and collect more data, are aware of the environment and context, and provide a better experimental experience to help people and machines.

- **Processes:** Processes happen between all the components (pillars) of the IoE. With the right processes in place, these connections become more valuable. They should convey the right information to the right person at the right time and in the most relevant way.
- **Data:** Information produced by people and objects. Combined with data analytics, these data provide actionable information for people and machines. Better decisions are made, and better results are achieved.

The structural framework of the IoE is shown in Figure 2.

Figure 2. Structural framework of the Internet of Everything



Source: Kanade (2022).

The nature of IoE innovation depends intensely on big data analytics due to the massive volume of crude information created. Big data examination is the method of handling an expansive and complex volume of information and distinguishing and anticipating patterns. Different encounters and proof demonstrate that big data examination can illuminate numerous trade issues. Although each of these technologies can create significant opportunities for businesses, combining these technologies seems to lead to a major transformation in the

supply chain. For example, IoE technology, with the help of devices and sensors, leads to an increase in the speed of receiving information on the status of the supply chain. However, big data analysis by processing this large volume of generated data brings pattern identification and trend prediction. This analysis can be based on other powerful technologies, such as AI. In collaboration with huge information analytics, IoE makes a difference in business change from being receptive to being proactive (Lerman et al., 2022). The concurrent utilization of these two innovations will increment the proficiency of the supply chain and hence pull in client fulfillment. Businesses that can utilize this innovation will end up in information-based commerce that can create choices based on genuine information, form opportune choices, and, for the most part, increase commerce efficiency. Therefore, it can be seen that IoE also moves in the direction of supply chain stability. The entire green IoE lifecycle should focus on green design, green production, green use, and green removal/recycling at the level of all processes so that there is no or very little impact on the environment. By monitoring all aspects of this technology and emphasizing big data in all dimensions, stability can be increased to a great extent. The most essential functions of the green IoE-based supply chain (GIoESC) are shown in Figure 3.

Figure 3. Green Internet of Everything-based supply chain components



Source: Adapted from: Ahmad et al. (2022).

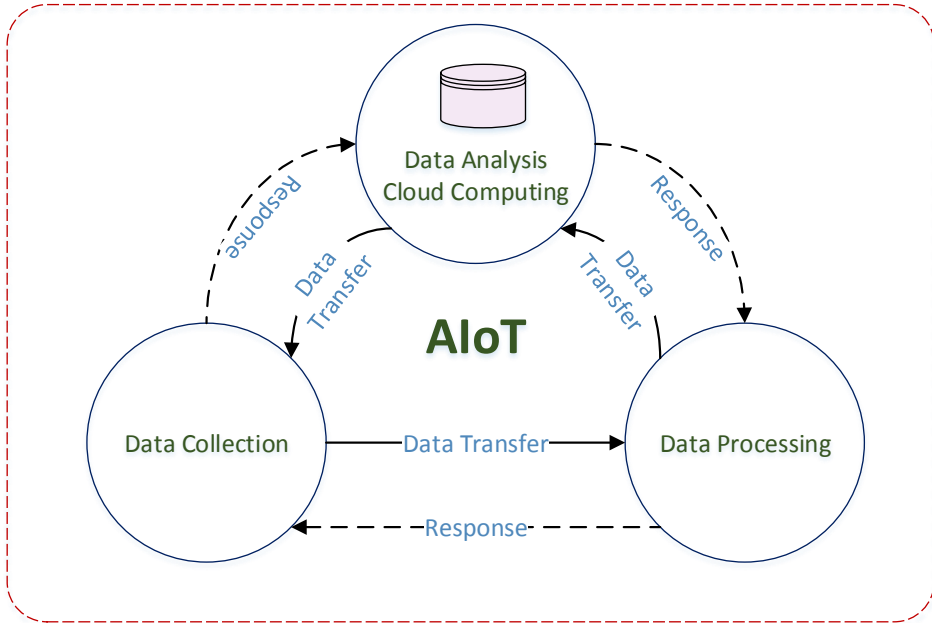
2.3. Artificial intelligence of everything

Although the world of IoE is not very old, it is rapidly adopting new technologies. Intelligence and automation are two crucial elements in information technology. However, the question is how these two can be connected with another significant movement developing with incredible growth. The business world is rapidly changing with the application of IoT and AI (Nozari, 2024a). IoT is collecting a significant amount of data from many sources. Nevertheless, collecting, processing, and analyzing data from countless devices is very difficult. The productivity and efficiency of an intelligent system increase in combination with other technologies, such as Machine Learning (ML). AI and ML are sometimes used to refer to the concept of creating intelligent software. This intelligence enables them to study information and make decisions like the human brain does. Given that the purpose of IoT devices is to collect and use data, ML and AI allow us to understand and improve the data collected from physical devices. Expert systems are used in IoT to add more value to IoT by better understanding data obtained from connected devices. As a group of connected devices collect and aggregate raw data, software programs with machine intelligence capabilities analyze the data. After a thorough review, the final result contains valuable information. In this manner, taking advantage of the combination of AI and IoT constitutes AIoT innovation, giving an exhaustive run of points of interest for businesses and shoppers, counting personalization of the client involvement and brilliantly mechanization (Nozari et al., 2023). AIoT architecture is shown in Figure 4.

IoE goes beyond the IoT and includes and connects all people, processes, and data in addition to things. Therefore, combining this technology with AI can create a super-advanced spring that adds great capabilities to business systems. These capabilities include collecting, refining, and analyzing big data in the shortest time, in the highest state of accuracy and security. Combining IoE technology with AI creates an advanced AIoT technology called AIoE. This concept was proposed for the first time in 2024 by Nozari (2024b). This technology includes and connects all elements of business and life systems. Because this technology always faces severe security challenges, security and privacy standards are very important. AIoE crunches ceaseless streams of information and finds designs that conventional measurements cannot distinguish and find. In expansion, ML combined with AI can foresee operational conditions and recognize parameters that ought to be changed to realize what comes about. As a result,

a brilliantly IoE that envelops all individuals, forms, things, and data can distinguish which information and processes are repetitive and time-consuming and distinguish errands that are fine-tuned to extend proficiency.

Figure 4. Artificial Intelligence of Things architecture



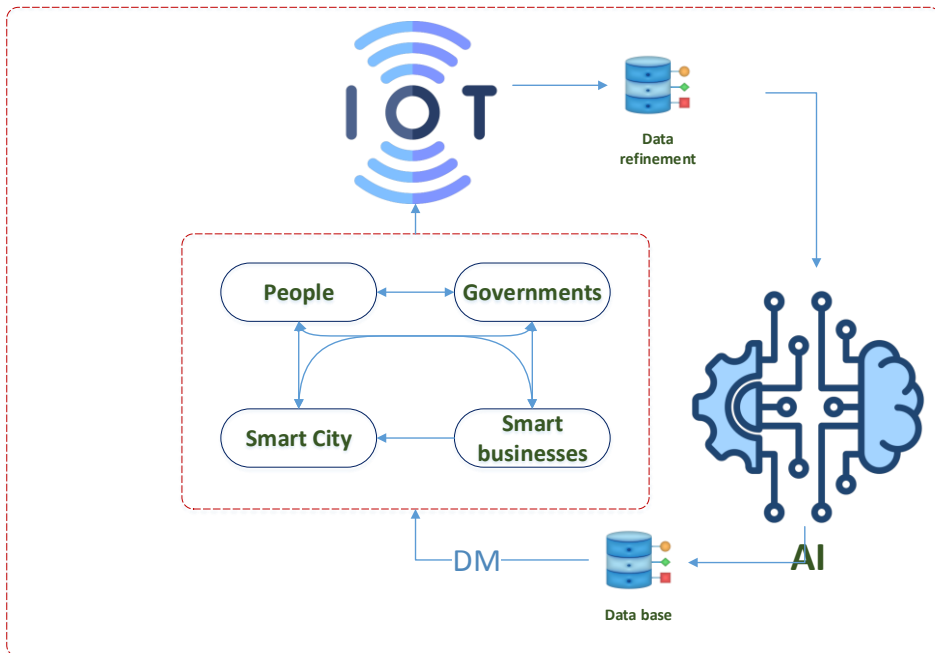
Source: Adapted from Huang et al. (2021, p. 5).

AIoE offers a unique opportunity to improve learning and personalization simultaneously. These AI frameworks all work well with other AI frameworks. AIoE can analyze vast volumes of information sent and gotten through gadgets. Since the entire strategy is based on machine and computer programs, it can be completed without human intercession, killing the blunders caused by human botches and moving forward in precision.

Prescient analytics is an expository strategy that examines existing information and predicts conceivable future occasions based on discoveries. Businesses presently utilize IoT gadgets to inform of any occurrence or hardware disappointment in a computerized way without human intercession. By joining the AIoE-based clever framework, organizations can to perform prescient analytics. With this sort of examination, companies appear they foresee mishaps and disappointments that are highly likely to occur and secure the gadget against conceivable dangers.

As a result, the likelihood of misfortune is enormously decreased, since disappointment is recognized some time recently it breaks and harms another portion. This will, without a doubt, result in noteworthy fetched investment funds for giant companies and offer assistance to them in maintaining a strategic distance from trade issues. Before sending data from one device to another, the AIOE ecosystem analyzes and summarizes it. As a result, large amounts of data are compressed into a manageable size, enabling the connection of a large number of IoE devices. Overall, AIOE has the potential to provide you with the best solution for an enhanced system performance experience. You can improve your business by integrating AI and data received from IoT devices. Integrating two advanced technologies leads to intelligent devices that help companies make strategic decisions with zero error and maximum security. The framework of AIOE is shown in Figure 5.

Figure 5. Framework of Artificial Intelligence of Everything



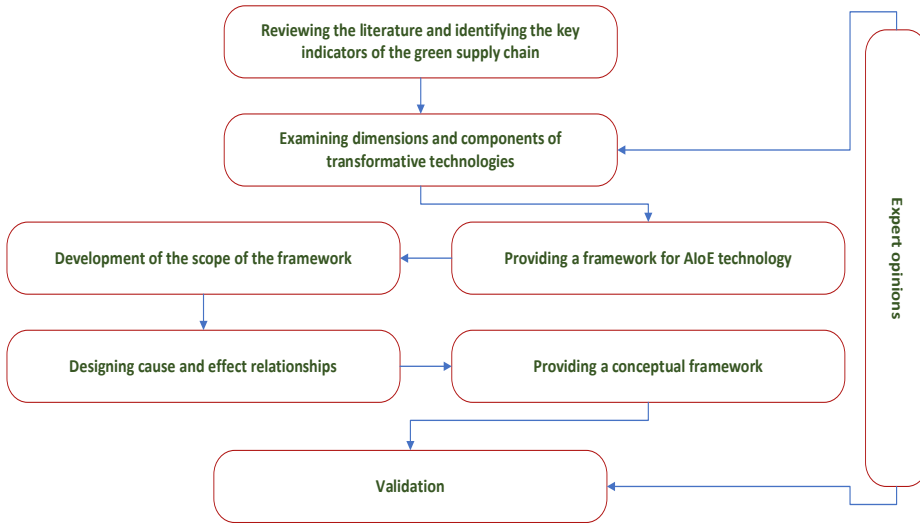
Source: Nozari (2024b, p. 7).

Although AI and IoE are two different technologies, their combination can improve various processes and applications more efficiently, intelligently, and effectively.

3. Research mythology

In this research, a conceptual framework for green supply chains with an emphasis on AIoE technology is presented. This research is applied and exploratory, and its results can have many applications in industries. This framework shows the cause-and-effect relationships of the actors. The tool used for this research is a questionnaire. The opinions of experts active in the supply chain and information technology field have been used to validate this framework. For this purpose, the framework was provided to 15 experts active in the industry and five academic experts, and after receiving their opinions, it was revised and modified. Finally, it was reviewed and finalized by experts. The research methodology is shown in Figure 6.

Figure 6. Research methodology



Source: Author's own elaboration.

As shown in Figure 6, after extracting the dimensions, components, and indicators affecting the green and sustainable supply chain, the range of technology effects is extracted and selected using experts' opinions.

4. Green AIoE-based supply chain

With the growth and development of transformative technologies, the green development of these technologies is increasing every day. A green supply chain refers to a set of processes used during a product's design, production, distribu-

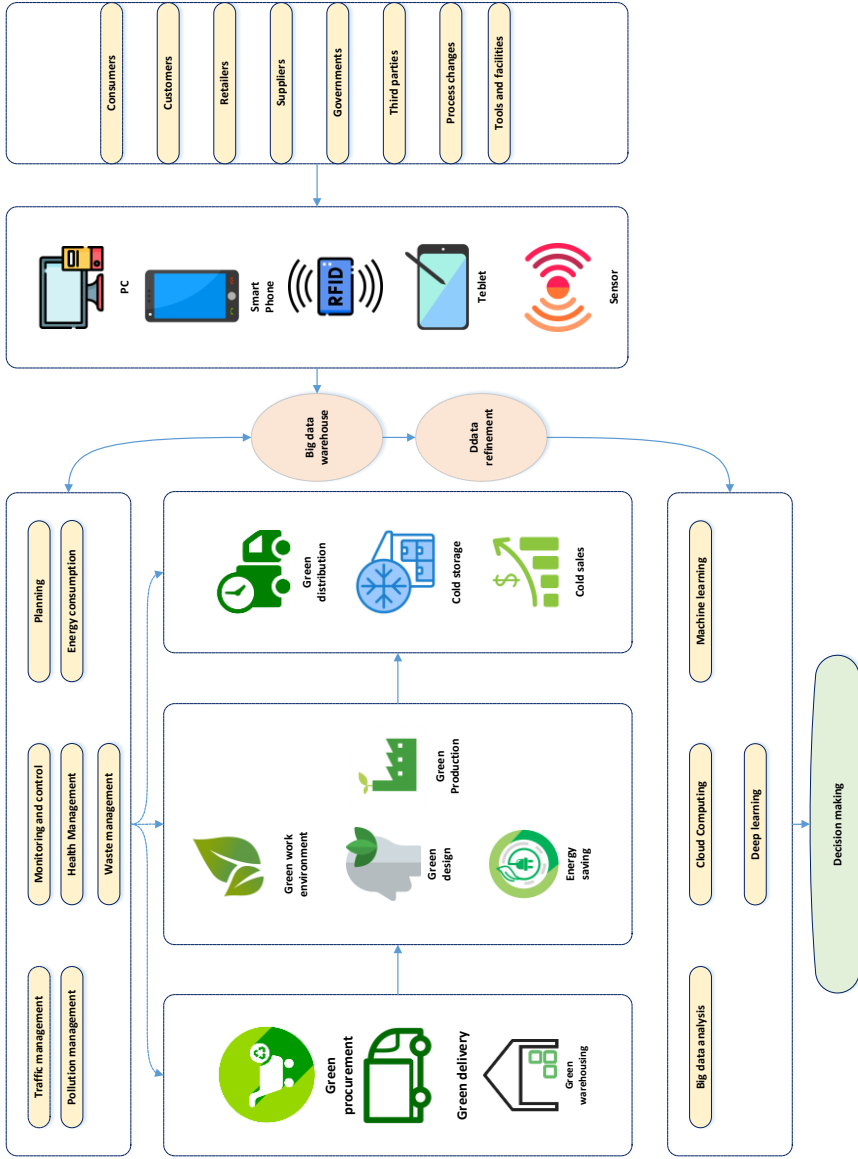
tion, consumption, and recycling to minimize the harmful effects on the environment and the consumption of non-renewable energy resources. This is why GSCM is considered a modern but necessary management model to protect the environment. The green supply chain has various components, among which we can mention:

- Green materials: use of quality and non-toxic raw materials as well as renewable energy sources in the production process.
- Green production: In many countries, it is known as clean production, during which the least pollution enters the environment.
- Green consumption: choosing products and services that are produced with complete compatibility with the environment and not using products that can be harmful to the environment.

As a powerful technology that can extract data on all things, processes, and people, AIoE technology can support green and sustainable supply chains. IT technology can include all chain elements from procurement to sales and distribution. Continuous monitoring of supply to confirm sustainable and environmentally friendly raw materials is one of the most basic functions of this technology in the collection and learning analysis of data in the green development of processes. It is monitoring the production process with an emphasis on reducing energy consumption, monitoring and measuring the production of environmentally friendly products using IoE systems, comprehensive monitoring of the optimal performance of production systems and preventing destructive functions, and monitoring the health of employees by examining all aspects of the conditions. Health in the operating environment, timely distribution monitoring, and emphasis on environmentally friendly distribution processes are among the functions of the green AIoE system in the supply chain processes. Therefore, it can be easily seen that this powerful technology in supply chain processes has amazing green effects. Of course, this issue should also be considered, as it brings challenges. One of the most critical challenges is security and privacy. Of course, AIoE is defined as a technology that goes beyond the fifth industrial generation and is therefore considered a technology with high analytical power speed and maximum security.

This framework shows the functional scope of this technology in the green supply chain. The green supply chain framework based on AIoE is shown in Figure 7. The presented framework has been evaluated and validated using the opinions of 20 experts as a focus group. Based on empirical and scientific knowledge, the experts examined and validated this framework using the criteria of integrity, comprehensiveness, and effectiveness.

Figure 7. Green supply chain framework based on AIoE



Source: Author's own elaboration.

5. Conclusions

Smart supply chain is an innovative approach to supply chain management that uses various IT methods to automate all parts of the process. In this way, it is possible to predict the necessary quantities of each product in the chain at all times, identify bottlenecks, and view data related to inventory and their correlation in real time. This facilitates the management of the entire chain, enabling companies to make informed decisions about managing their resources and react quickly to changes in demand or unexpected disruptions in the supply chain. The important point is that a truly “intelligent” supply chain is a self-healing and flexible system that can operate in an unpredictable environment. A smart supply chain also involves seamless information sharing, a partial reliance on automation, and continuous optimization of workflows based on real-time data.

Transformative technologies such as the IoT, AI, and blockchain have changed supply chain processes tremendously. With these technologies, extracting data that was not determined before is possible. By using learning-based systems, a powerful analytical capability has been created that was not possible before. Hybrid technologies are also increasingly powerful in the new age. AIoT technology gives processes the ability to analyze in real time. The combination of IoE technology, which includes all objects, processes, and people, with AI technology creates a new hybrid technology that has high computing power and, in addition, guarantees all-around security to an acceptable level. This hybrid technology is called AIoE. This technology increases green capabilities in the chain by comprehensive monitoring throughout the supply chain. From the supply of raw materials with an emphasis on environmentally friendly materials to green and optimal distribution is guaranteed by using this comprehensive technology.

This research tried to examine and evaluate a green supply chain’s dimensions, components, and critical features, emphasizing the combined technology capabilities of AIoE. Furthermore, a conceptual framework for green supply chains based on AIoE has been presented by determining the causal relationships of all actors in green supply chain processes. The opinions of active experts in the field of industry and academic experts have been used to validate this framework. Experts have approved the final cut. Examining this framework can provide a detailed insight into understanding these smart, green, and sustainable systems.

These analytical frameworks can show the dimensions and actors active in different parts of a system and the degree of effectiveness. However, the creation of these frameworks always comes with limitations. One of the most important limitations for presenting the framework presented in the research has been finding experts with sufficient awareness, knowledge, and experience and, simultaneously, participants for the analysis of cause-and-effect relationships. Moreover, the validation of the framework was accompanied by challenges due to some contradictions in the opinions of some experts, which required multiple meetings with experts.

Due to the importance of a green supply chain and the use of growing technologies in the new era in order to improve the sustainability of various process-oriented systems, much research can always be presented. For this purpose, it is suggested for future research to use the provided frameworks to provide quantitative models to investigate the effects of this smart technology in the development of sustainable systems. It is also possible to offer other hybrid technologies, such as the Blockchain-IoT, to develop green and sustainable supply chain financing systems.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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