AIoT-based Sustainable Smart Supply Chain Framework

Alireza Aliahmadi[1], Hamed Nozari[2], Javid Ghahremani-Nahr[3][1]

[1]*Professor of Management & Industrial Engineering, Iran University of Science & Technology, Tehran, Iran*
[2]*Faculty of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran*
[3]*Faculty member of ACECR, Tabriz, Iran*

ARTICLE INFO	ABSTRACT
Received: 12 February 2022 *Reviewed: 13 April 2022* *Revised:15 April 2022* *Accept: 30 April 2022* ***Keywords: Sustainable Supply Chain, Intelligent Supply Chain, Artificial Intelligence Things (AIoT), Internet of Things***	**Purpose**: Supply chains in today's global environment operate in a market that is increasingly complex and dynamic in nature. In such an environment, a stable supply chain to respond to drastic changes in customer needs becomes inevitable. Based on these studies, it is obvious that organizations operating in the field of supply chain should accelerate their focus on sustainability and use technologies such as "Internet of Things" (IoT) and artificial intelligence to achieve the organization's goal of creating sustainable processes. **Methodology:** The presence of the Internet of Things, along with artificial intelligence technology, has created Artificial intelligence of things (AIoT) technology, which gives the big data from the Internet of Things great power. In this research, an attempt has been made to study and analyze the key dimensions, components and indicators of the AIoT-based sustainable supply chain. Also, a conceptual framework for Padidar intelligent supply chain based on these evolving technologies is presented, which can help to understand the elements of this intelligent supply chain in order to optimize. **Findings:** A study of the literature shows that investing in this technology to achieve sustainable benefits is inevitable. In addition, the use of this technology due to networking and the presence of the Internet requires appropriate security solutions for information technology, a workforce with the required set of skills, sharing information in an integrated environment with business partners. **Originality/Value:** The generalities of AIoT-based sustainable supply chain components in general, and things can be added to different industries and behaviors. Understanding the dimensions of this framework can always help to implement it effectively.

1. Introduction

The supply chain is an integration process between different institutions such as suppliers, manufacturers, distributors, and sellers that seeks to create value for the end customer through various activities and processes. Sustainable supply chain management is the supply chain management in which all three dimensions of sustainability; That is, it is considered economic, environmental and social [1].

Supply chain sustainability as a new and influential issue has recently attracted the attention of researchers in the field of supply chain management. Because the supply chain considers a product from the processing of raw materials to the delivery of the customer and sometimes vice versa (reverse logistics), so focusing on the supply chain in a sustainable development environment will be a step forward to more broadly adapt the production environment to sustainable development [2]. Changes in production policies are forcing both manufacturers and researchers to seek to improve operations in terms of sustainable supply chain development. In sustainable supply chains, social and environmental criteria must be applied by members in order to survive throughout the supply chain, while a competitive environment is expected to be maintained by meeting customer needs and related economic criteria [3]. The growing importance of sustainability in the supply chain of organizations in the current turbulent world has led organizations to examine the impact of sustainable supply chain as a factor affecting the quality of products and services, proper provision of social services, and proper use of renewable resources [4].

The growing information and the role of the Internet in human life have marked new events that have changed the process of doing things in a new way. Connecting users to the Internet and exchanging information, communicating objects through sensors, tags have created a network of objects that provide connection and communication between objects at any time and place [5]. Today, the Internet of Things has facilitated the development of new applications in various fields and the improvement of existing applications [6]. This emerging technology not only causes change but is itself a response to change towards sustainable development in society. Having modern IoT technology is one of the indicators of economic development and growth in countries. This index, along with other factors such as skilled labor, natural resources and investment in various industries, has a significant impact on the level of development [7]. Artificial intelligence, on the other hand, has great potential to help address the complex and interconnected challenges of sustainable development, such as climate change, access to safety care, and inequality. By combining these two technologies, called artificial intelligence of things (AIoT), we will see a revolution in all sectors and industries. The combination of these two flows is in favor of greater stability of supply chain processes from supply to distribution and sales. While the Internet of Things deals with devices that interact with the Internet, artificial intelligence lets devices learn from their data and experiences [8].

AIoT breaks down constant streams of data and detects patterns that are not misleading on simple scales. In addition, machine learning with artificial intelligence can predict operating conditions and identify parameters that need to be modified to ensure ideal results. Thus, the IoT provides insight into which processes are redundant and time-consuming, and which tasks can be fine-tuned to increase efficiency. Thus AIoT facilitates the growth path towards supply chain sustainability [9].

Considering the importance of transformational technologies such as artificial intelligence and IoT along with technologies such as block chain in the sustainable growth of supply chains, in this study, the dimensions, components and key indicators of success of sustainable supply chains based on these

technologies have been evaluated. In this regard, an analytical framework for the AIoT-based sustainable supply chain is presented, which shows the causal relationships of the influential elements in this chain. Understanding these relationships can be an effective aid in the proper implementation of the smart sustainable supply chain.

2. Sustainable supply chain

Sustainability in the organization's literature and management has become a vital tool that guarantees competitive advantage and practice social responsibility. Sustainable supply chain is the consideration of social and environmental issues in all organizational processes. These processes include the entire life cycle of the supply chain from the purchase of raw materials to product design and development and warehousing and distribution and delivery of the final product [10]. Supply-chain sustainability is a business issue that affects the organization's supply chain and organizational logistics network based on environmental factors, production waste management and production. There has been significant growth in the need for integration of environmental activities with the organization's supply chain management [11]. A new approach to operations management in recent years is the supply chain sustainability approach.

In the organizational supply chain literature, the concepts of sustainable supply chain and green supply chain management are usually used interchangeably, but the two concepts are slightly different. Sustainable supply chain management includes economic, social and environmental sustainability dimensions [12]. So this concept is broader than green supply chain management. In other words, green supply chain management is part of sustainable supply chain management [13]. In recent years, the emergence of new technologies and the creation of huge changes in global markets has made the need to pay more attention to this issue. Different organizations have to use sustainable supply chain management theories to create, maintain their competitive position. Material flow management, information and coordination throughout the supply chain, considering three economic, social and environmental dimensions, is called a sustainable supply chain. Supply chain sustainability refers to the transparent integration and achievement of the social, environmental and economic goals of organizations through the effective coordination of internal organizational processes [14]. Key aspects of sustainable supply chain management practices include the sustainability of the supply chain network and supply chain environment, the application of environmentally friendly strategies, and the acceptance of social responsibility. Therefore, by considering the stability of the supply chain, in addition to considering financial profitability, adverse environmental effects and adverse social effects can be minimized [15]. Over the past decade, many organizations have engaged in activities such as lean manufacturing and total quality management. As a result, they will be able to achieve improved quality and at the same time eliminate a lot of extra costs outside their system. However, there is still room for improvement. Now there are opportunities mainly in supply chain procurement, distribution and support [16]. Sustainability must integrate the processes and flows that exist at the core of the supply chain. These processes include: product design, production, distribution and end products and regeneration processes [17].

- ***Product design***: The methodology for evaluating environmental arguments at the product design level should be looked at. This can help determine how the product is designed to reduce its environmental impact after use. Integrity between product design and processing phase must be discovered to reduce the harmful effects of the environment and guarantee long-term sustainability.
- ***Production***: Research at the level of the production process should focus efforts on developing a cleaner production process and reducing the production of by-products that may cause environmental degradation and human health. Process technologies must be designed and implemented to easily record reusable products while reducing the use of natural resources.
- ***Distribution***: Transportation emerges as a major distributor for the supply chain. Reducing greenhouse gases through cleaner transportation methods with a precise definition of supply chain structures contributes to a positive drive towards sustainability.
- ***Regeneration Processes***: The efficiency of end-of-life recycling using reverse chain is a rapidly growing field. The initial design of the product has a major effect on reuse, reconstruction, recycling, incineration or destruction of the product. Efforts on how to capture residual value in products at the end of their lives should be expanded.

The process systems engineer plays an important role in each of the above areas and contributes to an overall life cycle assessment to achieve these goals. The development of systematic methods and tools that ensure the design of environmentally safe products and processes related to a sustainable supply chain are goals to be implemented [18]. The sustainable supply chain cycle is shown in Figure (1).
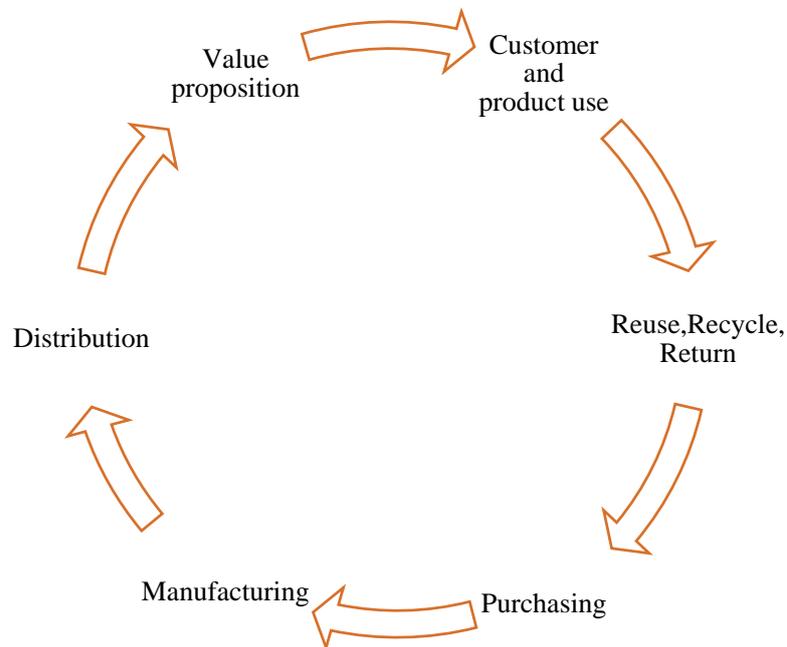

Fig. 1. Sustainable supply chain cycle [19]

3. Artificial intelligence of things (AIoT)

The business world today is changing with the advent of the Internet of Things (IoT) and artificial intelligence. The Internet of Things is helping to gather huge amounts of data from several sources. However, the collection of large amounts of information obtained through the myriad of IoT devices complicates data processing and analysis. Achieving the goals and full potential of IoT devices requires investing in new technologies. The convergence of artificial intelligence (AI) and the Internet of Things can redefine how industries, jobs and the economy work. Artificial intelligence uses the Internet of Things to create intelligent machines that simulate intelligent behavior and support decisions with little or no human intervention [20]. Recent studies have shown that these are two well-known technologies that are used today. They were also found to be the best technologies that companies invest in to increase efficiency and create a competitive advantage. The complete combination of the Internet of Things (IoT) with artificial intelligence (AI), known as AIoT, allows companies to take advantage of both at the same time [21].

"AIoT" simply means using the Internet of Things to perform intelligent tasks with AI integration. AIoT helps connect IoT devices to sensors that have AI capabilities, and all this is done without human intervention. While the Internet of Things provides data, artificial intelligence has the power to gather responses, providing both creativity and the ability to guide intelligent action. Because sensor-delivered data can be analyzed with artificial intelligence, businesses can make informed decisions [22]. A Logical Framework for AI and IoT is shown in Figure (2).
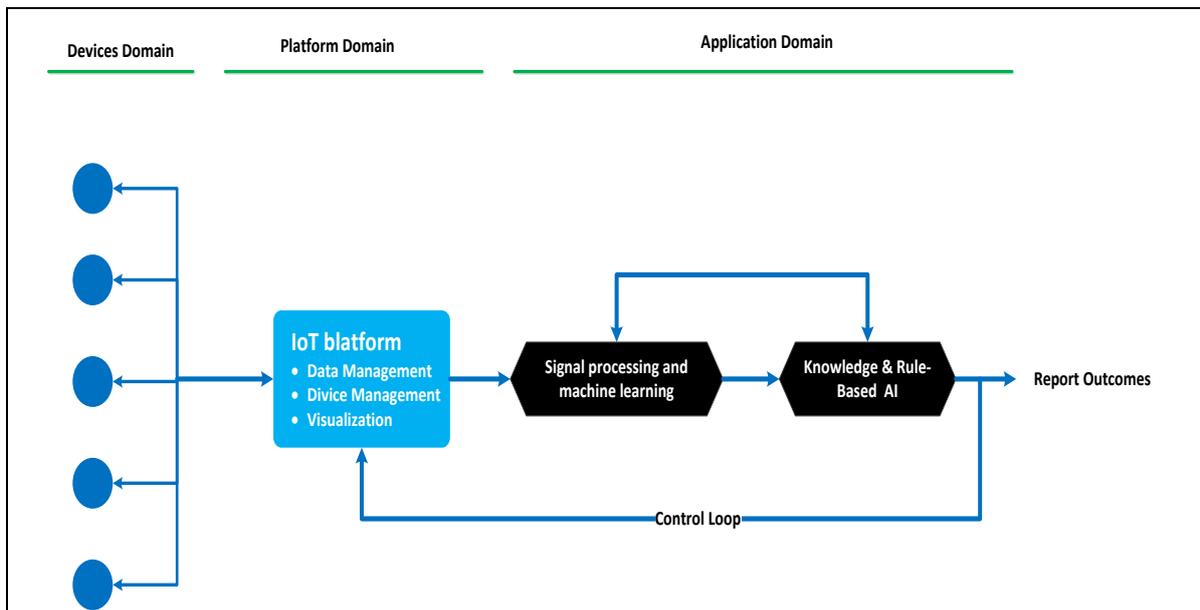

Fig. 2. A Logical Framework for AI and IoT

3.1. AIoT Features

- AIoT is the brain that controls the nervous system to make better business decisions.
- AIoT, which provides intelligent decisions, requires software code written by programmers to perform various tasks.
- AIoT is the next generation of the Internet of Things, and its primary design goal is independent operation without human support using artificial intelligence algorithms and predictive maintenance.
- In AIoT, IoT self-correction devices are created by analyzing data for better decision making.

3.2. AIoT Benefits for Businesses

- *Smart business decisions*

The data that millions of IoT devices collect is so large that it is difficult to separate and extract useful information from it. In order to organize this unstructured data into meaningful datasets, artificial intelligence-based algorithms are used to remove useless data and maximize the use of any business model.

- *Increase operational efficiency*

Intelligent automation works better than traditional methods by simplifying organizational processes.

- *Creating pleasant experiences for the customer*

With the help of AIoT technology, customers' behavior and challenges can be more accurately understood. For example, security cameras are not only used to detect any criminal activity or theft, but they can also be useful for examining customers' purchasing patterns.

- *Accurate predictions of consumer behavior*

AIoT helps make more accurate predictions in the future. One of the most powerful uses of AIoT is the automated robots used for delivery. These robots have built-in sensors that collect and store data received from IoT devices.

With this technology, businesses can better and more accurately identify the needs of customers and design and supply their products in line with these needs. So AIoT technology has many benefits not only for businesses but also for customers and end consumers.

Intelligence in AIoT is data analytics that is used to optimize the system and create better performance in the business. This intelligence helps to create data for better decision making and system learning.

4. AIoT and sustainability

In the age of technology, human beings must be able to make the best decisions using raw data and by turning them into information, make multifaceted decisions to preserve diverse resources for future generations. On the other hand, it must take a step towards creating intelligent machines and tools in order to achieve superior decisions by using the data mining symbol [23]. The Internet of Things is one of the most important sources of big data production and artificial intelligence is one of the scientific trends that can explore and analyze the pattern between raw data and identify the pattern between different phenomena to help people make optimal decisions. Developed systems today are systems that have access to information, and access to information is not a necessity, but a power, and businesses try

to design systems in an integrated and purposeful way so that the various components are closely interconnected and interact in many ways to make comprehensive and purposeful decisions [24].

Developed systems today are systems that have access to information, and access to information is not a necessity, but a power, and businesses try to design systems in an integrated and purposeful way so that the various components are closely interconnected and interact in many ways to make comprehensive and purposeful decisions. Extensive technological changes led by IoT, AI, and robotics all promise to change industrial and commercial processes. On the one hand, there is the deterioration of the climate and the environment, as well as geopolitical instability, all of which require a new approach that prioritizes the conservation of resources and environmental sovereignty - and in particular, intensifies efforts to decarbonize the atmosphere [25].

The Internet of Things creates a comprehensive connection between objects and the Internet, and in addition to discovering big data, it also helps to make data transparent and honest. Blockchain technology also helps maintain decentralized records and increases the security and privacy of IoT data. Artificial intelligence plays an important role in achieving the goals of sustainable development not only environmentally, but also from ending hunger and poverty to achieving sustainable energy and gender equality to the conservation and conservation of biodiversity [26].

With today's advances in IoT sensor technologies and wireless connectivity, the two concepts of digital innovation and sustainability have been mutually reinforced. Companies need to embrace digital transformation and its important business insights to focus on more energy-efficient practices, use more resource responsibly, and organize processes in ways that reduce waste. Effective ways that companies can use the Internet of Things and artificial intelligence and combine them to achieve sustainability are:

- *Smart Energy Management*
- *Air Pollution Monitoring*
- *Smart Waste Management*
- *Fleet Management*
- *Smart Water Management*
- *Cold Chain Monitoring*

While technology has in the past influenced environmental sustainability efforts, it has now become an ally in building a greener, more sustainable planet. Advances in IoT sensors and wireless connectivity allow individuals, companies, and governments to move toward energy-efficient, more responsive resources. Also, using the analytical power of artificial intelligence machine learning technologies, organize processes in ways that reduce or reuse waste, which is itself a more effective and powerful step in the development of sustainability [27].

5. AIoT-based Sustainable Smart Supply Chain

In today's world, sustainability has become one of the most important concerns of any organization in various industries. Research shows that high-ranking companies perform better in the medium and long term for environmental, social, and equity factors [28]. Supply chains have a huge direct impact on society, the environment and financial performance. With the right use of the latest technologies, supply chains have more potential to create and encourage a sustainable world [29]. Artificial intelligence and the Internet of Things work together in the business world to improve business processes and productivity. Using a combination of technologies such as the Internet of Things, artificial intelligence

and blockchain, companies can reduce greenhouse gas emissions, optimize routes, reduce waste, ensure efficient transactions with suppliers, improve worker safety, and Reduce risks.

We can find better driving directions by using the integrated IoT solution and other technologies. Therefore, it is possible to reduce the fuel consumption of diesel and gasoline used by freight vehicles, which are one of the largest consumers of energy and contributors to greenhouse gas emissions. With IoT technology, we can track all goods from origin to destination and view them in real time. So we can reduce all kinds of damages, thefts and damages. IoT technology can also be used to improve safe working practices, which is one of the main concerns of any manufacturing and logistics company. Internet-connected sensors can be placed around a factory or warehouse and used by workers. Activity and movement data can be analyzed to quickly detect any dangerous or hazardous behavior.

On the other hand, AI based on data from IoT tools can instantly analyze vehicles, volumes, routes and stops to identify optimal opportunities to share transportation with other organizations. Transport sharing not only helps reduce shipping costs, it also reduces environmental impact. Artificial intelligence can also have a huge impact on an organization's sourcing activities. Artificial intelligence of things can be a very useful tool in accurately predicting customer demand. And so, companies use AIoT technology, the big data from the Internet of Things and the power of artificial intelligence analysis, to produce and send just what customers want to buy.
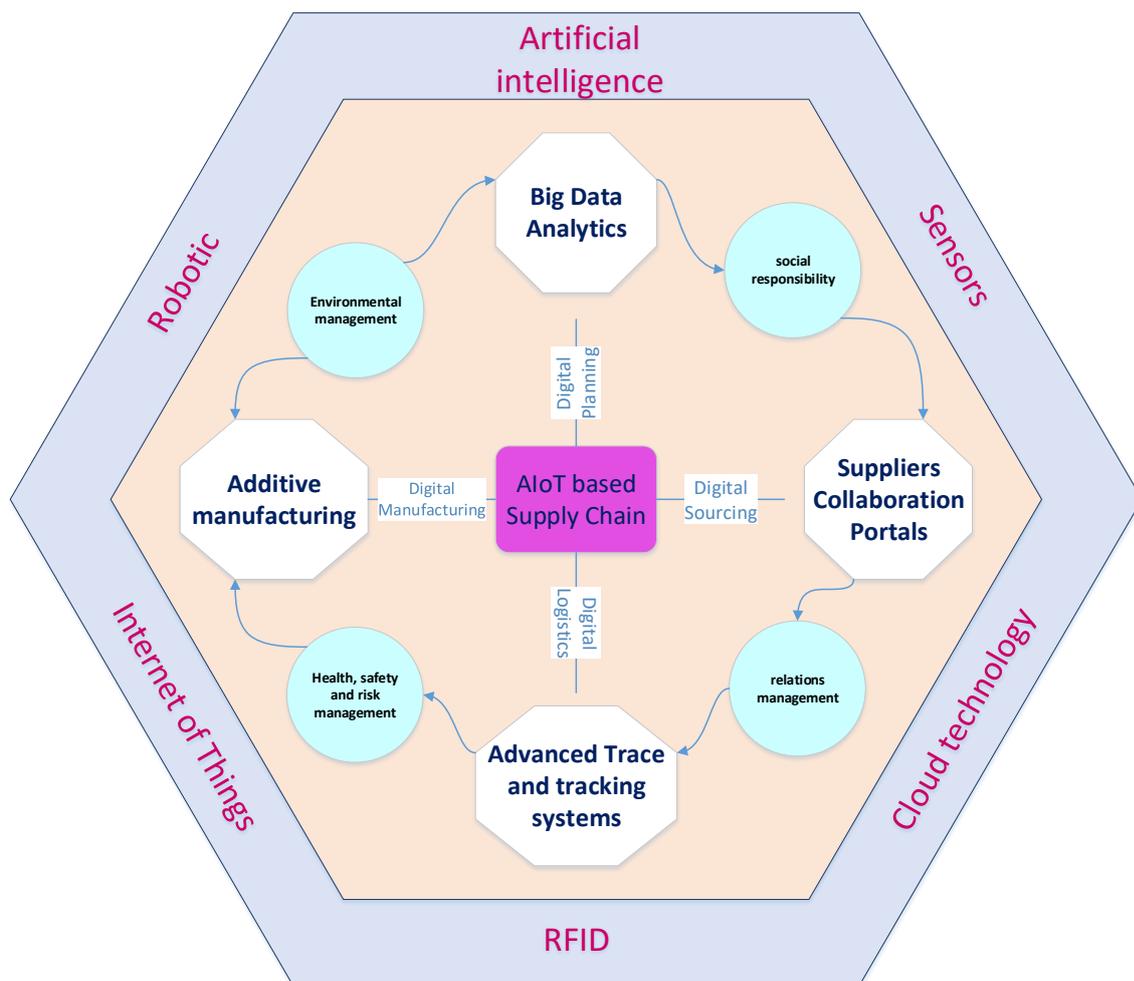

Fig. 3. AIoT-based sustainable supply chain conceptual framework

The goal of sustainable supply chains is to interact with direct and subsidiary suppliers and maximize the overall social, environmental and ethical impact. Technologies such as artificial intelligence, the Internet of Things and the Chinese blockchain can play an important role in achieving this goal and much more. Understanding technology and sustainability as a competitive advantage and focusing on system change, along with individual programs, is the secret to success to ensure long-term and lasting impact.

6. Conclusion

Today's world is focused on lower consumption options in all aspects of life. From transportation, retail and agriculture to consumer goods and services, the threat of climate change and rising energy costs, organizations have been forced to redouble their efforts to increase sustainability and reduce greenhouse gas emissions. Although these pressures for supply chain sustainability are sometimes seen as a way to satisfy the general public, the truth is that implementing and improving sustainability initiatives benefits an organization, both in the short and long term.

In this regard, organizations are gradually moving towards the implementation of digital technology, namely artificial intelligence and the Internet of Things, and their combined technology, namely artificial intelligence of things, to increase results. This guarantees broad prospects for competitive advantage and paves the way for future sustainable supply chain practices. AIoT helps provide the supply chain with a quick response to customer demand. Improves productivity and allows stakeholders to make faster decisions in real time. Certainly, ways to adopt new business models will pave the way for the improvement of the production process. The combination of IoT technologies and artificial intelligence gives analytical power to big data from the Internet of Things, increases decision-making power in supply chain processes, and increases supply chain stability in all social, economic, and environmental aspects.

In this study, various aspects of supply chain sustainability and its key dimensions and components along with AIoT technology have been studied in detail. The literature was analyzed to identify trends and potential AIoT opportunities in the sustainable supply chain space. Based on the review, a conceptual framework has been proposed to demonstrate the key influential elements in the AIoT-based sustainable supply chain for sustainable growth. The conceptual model is formulated based on the vision of intelligent technologies, sustainable development and cooperation. The proposed framework can be the basis for implementing a smart sustainable supply chain.

A study of the literature shows that investing in this technology to achieve sustainable benefits is inevitable. In addition, the use of this technology due to networking and the presence of the Internet requires appropriate security solutions for information technology, a workforce with the required set of skills, sharing information in an integrated environment with business partners. Thus, small industries may have difficulty implementing smart supply chains based on evolving technologies because they do not have sufficient financial resources to invest. Therefore, its implementation will be challenging for small industries. The proposed framework demonstrates the generalities of AIoT-based sustainable supply chain components in general, and things can be added to different industries and behaviors. Understanding the dimensions of this framework can always help to implement it effectively.

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