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Research Paper

A Conceptual Framework of Green Smart IoT-based Supply Chain Management

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A B S T R A C T

The green smart supply chain is a phenomenon that has emerged as a result of the development of sustainable and smart business and information technology trends. Sustainable and green supply chains are an innovative phenomenon that use information technology to improve the quality of activities in operating areas. In order to ensure that activities are adapted to social and environmental needs. In this regard, the Internet of Things (IoT) is one of the most important components of technology infrastructure for smart. For this purpose, in this research, a framework for implementing a green IoT-based supply chain is presented. This framework is based on the four-stage architecture of the IoT and has been created by emphasizing the literature and the interaction and review of the opinions of active experts in this field. This framework illustrates the direct relationship between data generation and how it interacts with the sectors affected by environmental sustainability and outlines a clear pathway for sustainable and green decision-making in the supply chain. This framework has been endorsed by experts in the supply chain field and can pave the way for effective implementation of the green supply chain with an emphasis on technology in manufacturing organizations.

Keywords: Green Internet of Things (G-IoT), Green supply chain, Smart business, Smart supply chain.

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1. Introduction

The concept of "green smart business" has expanded in recent years as a new form of sustainable development and represents a model that incorporates all alternative approaches to improving the quality and performance of a business in order to better interact between production and service space and customers. The modern business environment deals with data and this has created many challenges and opportunities. New information sources provide opportunities for new applications to improve the quality of business activities and their relevance to modern life. Business data is usually about the interactions between humans as well as the types of machines and tools that, in addition to their complexity, are a concern for privacy and security [1]. There is a great deal of information and financial interactions in the relationships between different parts of the business and the people involved in different parts of the supply chain through Internet-based systems as well as a variety of smartphones and tablets [2]. Route analysis data is used to indicate the desired route, depending on the current location and destination. The most advanced routing systems take real-time traffic into account and predict the best route by predicting different route traffic using random time spatial fields, which use past traffic data for forecasting [3]. IoT is one of the key components of a sustainable ICT infrastructure that is introduced because of its high potential to promote environmental sustainability [4]. The IoT, as a social human technology, leads to dramatic environmental and urban technological changes in complexity and diversity. Big data capability has been a key factor in implementing new IoT applications. Overall, the development of IoT, as a computational paradigm and analytical process of big data, promotes sustainable smart business initiatives and applications in the environmental field of advanced countries [5].

IoT enables the integration of digital and physical structures and provides a completely new class of applications and services that should be used with respect to the stability of the environment. This reveals the importance of concepts such as the green IoT. On the green IoT, sensors, devices, applications, and services are portrayed in terms of energy efficiency [6]. In the domain of green and sustainable smart businesses, increasing the volume of data generation is beyond imagination, and the vast amount of information available in different areas is of great value. Therefore, they can be used by planners and IT professionals to promote environmental sustainability. Despite increasing research on IoT and urban development data related programs, the bulk of the work is primarily aimed at economic growth and quality of life in smart cities and there has been little attention given to the green applications of IoT in business. Therefore, the main research question to be considered is: "How can the information landscape of sustainable smart businesses be enhanced by using IoT and big data processing programs with emphasis on environmental sustainability? Since there is always a shortage of innovative solutions based on IoT applications that can make an effective contribution to sustainable environmental development, this paper has attempted to inform the perspective of sustainable IoT supply chain as one of the most important parts of the organization covering a complete set of processes from supply to distribution and sales with an emphasis on green IoT. In this regard, a comprehensive analytical framework is presented (relying on the literature and opinions of highly experienced experts). This framework is based on the creation of big data (generated by IoT) with an emphasis on being green process. This framework illustrates the components of the green IoT-based supply chain implementation in a transparent manner. With this framework, effective points can be identified and by changing the influential parameters, it has made optimal decisions to sustain the environment for the supply chain. This research provides a basis for researchers to develop analytical frameworks for future research. The proposed framework can be developed and evaluated in empirical research and will lead to deeper studies in the field of sustainable intelligent systems.

The rest of the paper is organized as follows. Section 2 presents a review of the literature in terms of IoT, green IoT and green supply chain. In Section 3 green IoT supply chain management framework is provided, and lastly, the conclusions are presented in Section 4.

2. Literature Review

In order to illustrate the effects of green IoT concepts on supply chain management, a literature review of IoT technologies and green supply chain management is provided in this section.

2.1. Internet of Things

The term of IoT was first introduced by Kevin Ashton in 1999. Using the IoT Everyone, plants and even lifeless objects (such as machines) can have digital identities for themselves. The Internet is now connecting all people. But with the help of IoT, all objects can be connected, managed and controlled using apps on smartphones and tablets [7]. In fact, the IoT is a new concept in the world of information technology that provides the capability to send data through communication networks such as the Internet [8]. The use of these technologies can also play a significant role in the growth of intelligent smart systems [9]. Nowadays, businesses have paid much attention to this issue. Because the IoT approach enhances the interoperability between objects as well as objects with humans, and with the help of such an approach, new services will emerge [10] and [11]. Various fields, such as e-health, e-commerce, and cloud-based production, have been transformed by the IoT. IoT is one of the most important ways to generate big data. Using this data, useful models can be created to optimize different business models [12]. Therefore, acceptance of IoT has many potential benefits. These benefits include improving operational processes, creating value, reducing costs and minimizing risks resulting from the flexibility created by IoT [13]. The IoT is built on the backdrop of applications that have created key empowerment for technology. These technologies include Radio-Frequency Identification (RFID), wireless sensors, smart technologies and nanotechnologies. These applications enable real-time monitoring and control of changes that occur in the physical state of the connected objects [14]. ***Figure 1*** shows the IoT ecosystem. Many research points to various uses of the IoT. The use of IoT in the healthcare industry has been discussed in numerous papers [15] and [16]. All technologies in the health system can be continuously tracked and monitored using technologies such as identity recognition and communication capabilities on the IoT [17] and [18]. The use of IoT in the supply chain has also been the subject of much research. IoT offers many solutions for tracking, observing and managing supply chain challenges [19]. IoT technologies can collect process and distribute data related to this chain [20]. The use of the IoT for safer production in mines is another area of research. IoT technologies can detect the occurrence of a mine accident and provide the necessary warnings. On the other hand, using accident data can predict the occurrence of the accident and improve mine safety [21] and [22]. IoT also plays an important role in the transportation and logistics industries. The greater the number of physical objects with RFIDs or sensors, the more logistics and transport companies can monitor the movement of objects from source to destination [23] and [24]. Many other studies have also addressed the link between IoT and smart cities and environments [25] and [26]. For this reason, the environmental applications and greenness of these technologies can be of great importance. So in the next section, we will introduce green IoT.

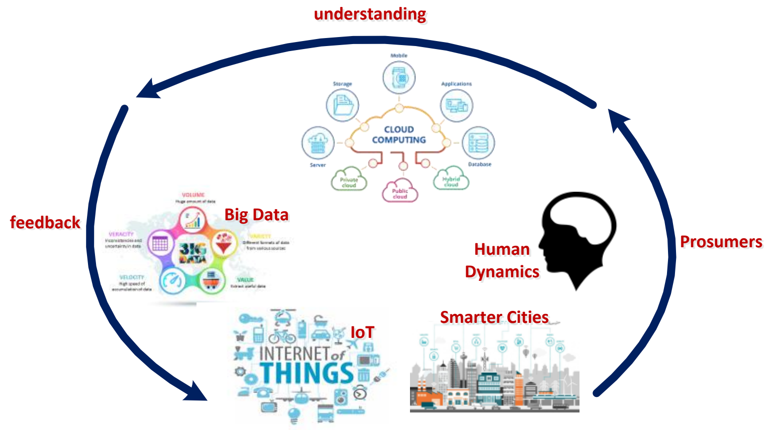

Figure 1. The IoT ecosystem [27].

2.2. Green IoT

The concept of sustainable smart business has emerged from important global trends, namely the dissemination of sustainability and the spread of ICT. This term, using IoT technology, becomes a more powerful concept. IoT involves the massive use of expected network and number nodes in the future. Therefore, there is a need to reduce resources to implement all network elements and the energy consumed for their operation. Today maintaining the ideal energy consumption rate has become one of the most important challenges in IoT research [28]. Therefore, Green IoT (G-IoT) is always essential to achieve lower energy consumption and to become a modern environment. To this end, all the key technologies associated with the G-IoT must be taken into account. These technologies include green tags, green sensing networks and green internet technologies [6]. These technologies are embedded in the lifecycle of the IoT and help sustain them. The life cycle of the IoT is illustrated in ***Figure 2***. One solution to achieving green RFID is to reduce the size of RFID tags and thus minimize the amount of non-degradable material [29]. In other research on green RFID, algorithms for RFID inventory with energy saving and optimization have been proposed [30] and [31]. In addition, in order to achieve a Green Wireless Sensor Network (WSN), different techniques have to be considered that have been mentioned in various studies. These techniques include [6]:

- The sensor uses the energy required to operate and then placed idle or sleep.
- Use energy-saving techniques.
- Use efficient routing techniques to reduce mobility energy consumption.

In the case of green internet technology, hardware and software should be considered, where the hardware solution produces devices that have less energy without reducing performance [32] and [33].

There are many applications to the G-IoT, such as Green Smart City, Green Smart Factories, Green Smart Healthcare and Green Smart Logistics. In the following, we examine the green supply chain that encompasses many of these applications.

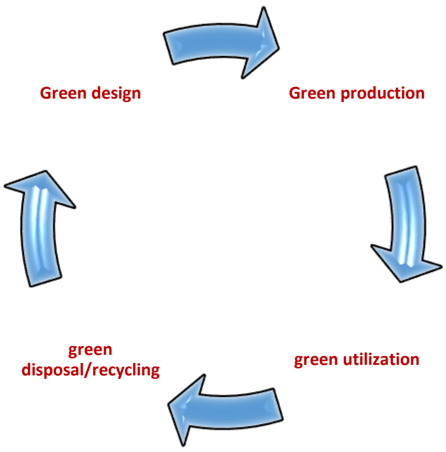

Figure 2. The G-IoT life cycle [6].

2.3. Green Supply Chain Management

Since the issue of environment was linked to the economy and countries have come to the conclusion that environmental protection can increase productivity, different approaches have been taken to realize these technologies, one of which is the latest, the Green Supply Chain Management (GSCM) approach. The idea of green supply chain management is to eliminate or minimize waste, which as an important innovation helps the organization to develop strategies to achieve common profit and market goals by reducing environmental risks and enhancing environmental efficiency [34]. The main drivers for green supply chain adoption are laws and regulations that dictate compliance with environmental issues. Other drivers of using the green supply chain can be increased capacity for transportation, recycling and reusable packaging, reduced use of resources (water and energy), compliance with environmental standards [35]. All interactions in the supply chain can provide valuable information for analysis and decision making [36]. IoT, as one of the most important sources of big data generation, plays a significant role in these interactions. Organizations gain competitive advantage by improving the environmental role of IoT and by adhering to environmental laws and standards, enhancing customer knowledge and reducing negative environmental impacts on their products and services. Since the supply chain is one of the most important organizational units and covers a large range of organizational processes from supply and supplier relationships and then to manufacturing processes and ultimately to sales, distribution and customer relationships, so considering environmental parameters in the supply chain can play an important role in the sustainability and greening of human life environment [37]. Therefore, adopting an investment strategy to improve the environmental performance of the supply chain will bring many benefits such as saving energy, reducing emissions, eliminating or reducing waste, creating value for customers and ultimately enhancing productivity for companies and organizations. Due to the importance of the issue, the issue of GSCM has been studied from various aspects. Some believe that supply chain greening, in addition to its environmental impacts, can also have a number of positive economic and operational implications and increase the efficiency of organizations [38]. Other studies have also suggested that the use of green technology in the supply chain, in addition to creating competitive advantage, can give the organization more flexibility and increase profitability [39]. In some papers, the role of IoT in the supply chain is also mentioned [40] and even models have been created to make the supply chain smarter base on IoT [41]. In the following, the IoT-based green supply chain is examined and analyzed.

3. Methodology

The present research is applied in terms of research (considering its general purpose, which is to identify, discover and explain the indicators and effective components in the IoT-based smart supply chain process) and the method of qualitative content analysis has been used in it; Because narrative data paints a more natural and realistic picture than numerical data. In order to extract the data in this research, literature review as well as review and evaluation of experts' opinions have been used. The experts in question were supply chain activists as well as information technology activists. In the present study, in-depth interview tools were used to collect data. First, the general question was, what are the characteristics of an IoT-based smart supply chain? Then, based on the answers provided, the following questions are asked. To check the validity of the data, the following measures were taken: 1) some of the final findings were provided to experts to review the researchers' perceptions and analysis, 2) data analysis and results were provided to several experts to express their expert opinion on data analysis and results, and 3) in order to increase the verifiability of the interviews, notes were taken. The data obtained from the interviews were analyzed using the thematic analysis method. Thematic analysis is a systematic approach to reduce and manage large volumes of qualitative data without losing context, immersing oneself in data, organizing, summarizing, and focusing on data interpretation.

4. Green IoT Based Supply Chain Framework

Sustainable smart supply chain emphasizes all processes of supply chain from supply to distribution with a view to energy efficiency and other environmental solutions based on ICT, IoT, and big data analytics. The results of these processes cover a variety of subject areas, including applications, sensor technology, data processing applications, and sustainable computing models. In its fullest sense, the smart supply chain is a chain of physical, social and economic smart infrastructures ensuring that businesses are focused on key features such as smart economy, smart mobility, smart people, smart environment, smart activity and smart management in a sustainable environment. Strategic use of new technologies and innovative approaches to increase efficiency and competitiveness are other features of this chain [42]. Objects, people, processes, and devices communicate with each other through an Internet-connected infrastructure in the IoT supply chain and generate a large amount of information. The data sources for generating big data in the IoT-based smart supply chain are shown in ***Figure 3***. The combination of smart supply chain and sustainable supply chain is less well known in the current definitions. This term refers to an innovative supply chain that uses information and communication technologies and other tools such as exploring big data from IoT to improve business quality, efficiency of operations, services and competitiveness to meet the needs of current and future generations, taking into account economic, social and environmental aspects. Since big data has very high diversity, variety and growth rate, traditional analytical systems are not suitable for their management. This means that big data processing involves the use of tools (classification, clustering, regression and other algorithms), techniques (data mining, machine learning, statistical analysis, etc.) and technologies that it is beyond the range of analytical methods used in extracting useful knowledge from a large volume of data for accurate and rapid decision making with the aim of increasing insight.

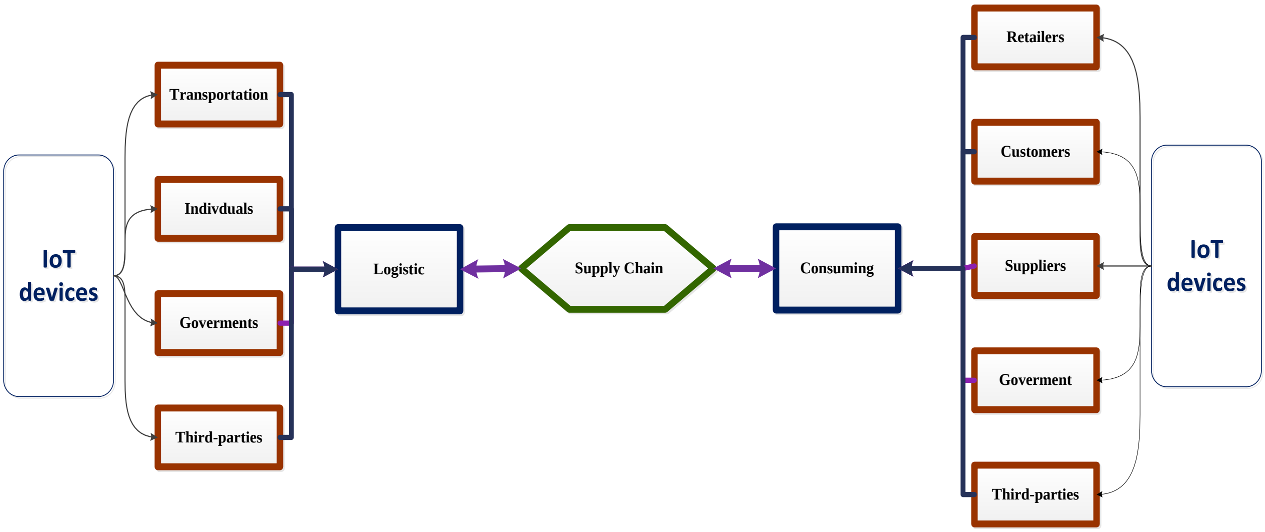

Figure 3. Big data sources in the supply chain.

In the context of sustainable smart supply chain, big data analytics refers to a suite of sophisticated software applications and database systems run by highly computing machines and capable of handling large data. Research on the uses of IoT and big data is active in the realm of smart businesses and is mainly related to economic growth and quality of activities. But the role of IoT and big data applications in promoting environmental sustainability in the field of smart green businesses as a holistic approach to development has rarely been addressed to date. In addition, IoT-based green supply chains have addressed the challenges posed by environmental sustainability arising from the disparity of ICT-based solutions with emphasis on green information and functional approaches. Given all that has been said, creating a framework for integrating the information and physical aspects of sustainable smart businesses is essential. Of course, in some papers, general conceptual models for the IoT and its applications are mentioned [43]. However, there is always a need to strengthen supply chain information using IoT as well as big data in order to increase their contribution to environmental sustainability. Therefore, dealing with complex mechanisms and patterns involved in the interaction between the environmental and physical systems of advanced smart businesses is crucial and these interactions affect the environment. However, in order to make an effective connection between the IoT supply chain as well as the green supply chain, first the key indicators that affect the green supply chain should be found. According to literature, the key performance indicators can be selected as shown in Table 1. As can be seen, the main places of influence of these indicators have also been identified. Given these performance indicators and the extent to which IoT data is used effectively in effective locations, a framework can be proposed to implement green IoT-based supply chains.

Table 1. Performance indicators of green supply chain.

PIs	Supply Chain Sector
Green purchasing	Supply
Green manufacturing	Production
Green design	Production
Green transportation	Distribution
Environmental management	Supply-Production- Distribution
Operational performance	Supply-Production- Distribution
Cold storage	Supply-Production- Distribution

This framework is created by emphasizing the four-layer architecture of IoT implementation [44]. Generally, these four layers respectively, include data acquisition, data refinement and analysis, data processing, and ultimately data integration and use (***Figure 4***). Therefore, the various sources of data involved in the supply chain must be collected, stored, processed, analyzed and integrated into operations, functions and plans in the field of environmental sustainability (with emphasis on key green indicators) and then the data should be shared. Processes associated with knowledge discovery include selection, pre-processing, modification, exploration, interpretation and evaluation. Data mining processes include information comprehension, data preparation, modeling, evaluation and deployment. These two processes are involved in areas related to environmental sustainability and their aim is to discover new knowledge or exploit large populations. Discovered or extracted knowledge includes information functions intended for decision making, decision support, and automated decision making. Information functions are used for real-time and strategic decision-making in the form of control, automation, optimization and management.

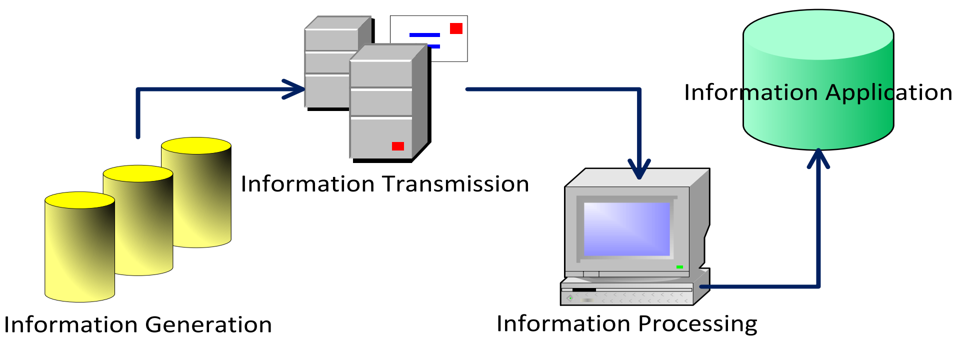

Figure 4. 4-layer architecture for IoT implementation.

Figure 5 shows a framework for deploying large-scale data processing using IoT technologies implemented on the cloud or in the fog in the green smart chain. These technologies include sensors, data warehouses and repositories, data processing platforms and cloud or fog computing models. In fact, this framework illustrates the effective link between input data and their green processing using IoT and their place in the supply chain. A review of the literature reveals that frameworks for smart cities using IoT have already been presented. Since a dedicated framework for the implementation of IoT-based supply chain and with the emphasis on sustainability and greening not previously provided, this framework can be very useful. In this framework, sensor data from different domains of the supply chain, which are collected, integrated, pre-processed and converted based on key performance indicators of the green supply chain, using data mining and machine learning techniques for model building Patterns, pattern recognition, correlations are used to automate, support, and make decisions in operations, plans, and other supply chain activities.

Cognitive analysis is intended to identify key conceptual themes in a sustainable green supply chain model that emphasize the use of IoT and big data processing in relation to environmental sustainability. These include sensor technologies, data processing platforms, computational models, and data-driven applications related to the various components of the supply chain. The main parts of this framework are described in ***Figure 5***.

Sensors and other communication devices such as tablets, smartphones have a direct relationship with the data sources in the supply chain. Therefore, these valuable data can be used through these tools as well as a variety of real and virtual transactions to improve environmental sustainability in the supply chain. Sensor data is available in a variety of formats, and there are various ways to capture and store this data. The extracted data have a large volume and their production speed is extremely high. At the same time, because they come from a variety of sources, their diversity is also high. As a result, these data are big data and need their own analytics tools. By interacting with these data and key performance indicators in the green supply chain, effective factors on environmental sustainability can be deduced and their performance improved. Some of these improvements can be demonstrated in traffic control, monitoring and optimization of fuel consumption, reduction of the pollution caused by the use of industrial machines, energy optimization, and so on. To achieve this goal, it is necessary to use specific analytical tools in the big data range. In recent years, cloud and fog computing have gained a lot of attention and become popular in the world. Therefore, by expanding distributed and networked computation on extracted and refined data in order to increase environmental sustainability, the possibility of optimizing processes as well as improving system performance and thus optimizing decision making is increased. One of the most important benefits of this framework is to provide a transparent process of implementation of IoT-based supply chain with an emphasis on environmental sustainability and identifying a well-established path for implementation. Accurate communication between data entry pathways as well as identifying the location of impact can guarantee optimal performance at the optimal time.

The framework presented in ***Figure 5*** has been provided to 30 supply chain professionals after repeated design and review. In this regard, a five-level Likert scale questionnaire was used to evaluate the experts' opinions. The results of the questionnaires confirmed the validity of the framework. Cronbach's alpha for the questionnaires using SPSS software was 0.9 which indicates good reliability of questionnaires.

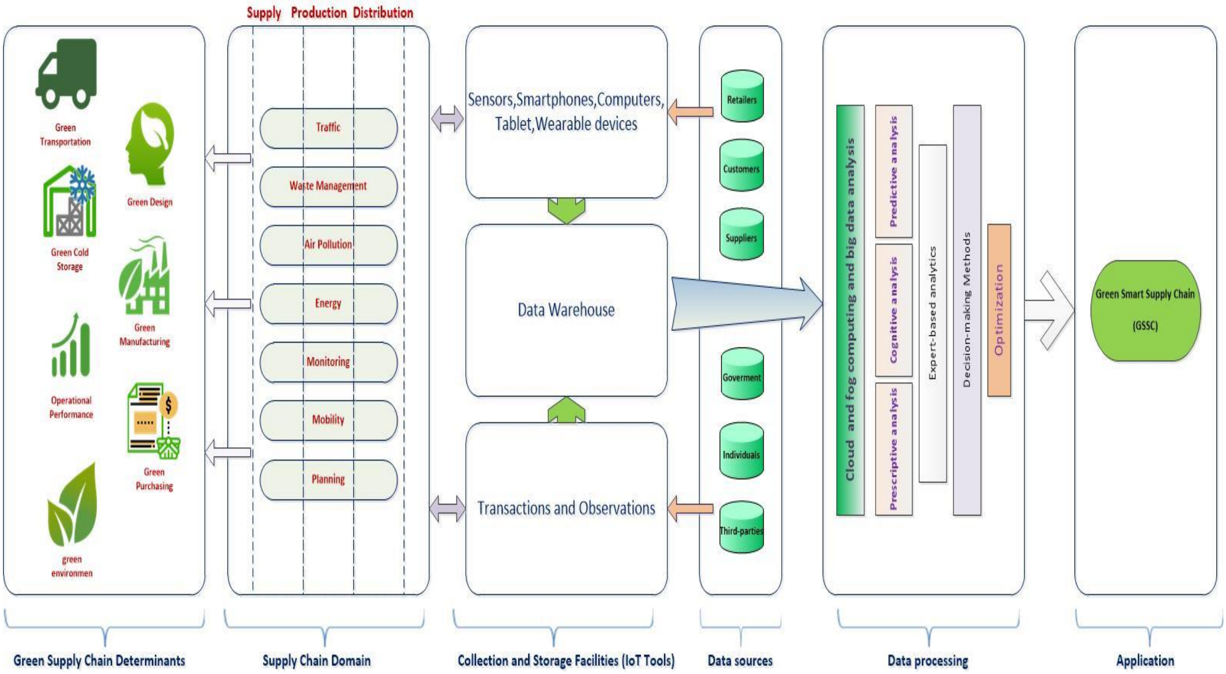

Figure 5. Green IoT-based supply chain implementation framework.

5. Conclusion

IoT is a new form of large-scale applications that, due to its operational performance, have received considerable attention from sustainable smart industries. Therefore, the potential of IoT and macro data analytics depends on such industries being able to optimize their information landscape by implementing and combining relevant frameworks to improve designs and services. There is high expectation for environmental gains from ongoing IoT research and big data analytics in science as well as industry. Therefore, the purpose of this paper is to review and integrate related literature and provides a framework for identifying and discussing the applications of Big Data based on advanced IoT enabled sensors for environmental sustainability and data processing platform in addition to green smart supply chain computing models. This framework provides an innovative multilevel methodology for implementing the green IoT-based supply chain that demonstrates the direct relationship between data in effective locations for environmental sustainability and their impacts using robust analytics. This framework outlines a clear path to implementing the green IoT-based supply chain and identifies influential locations. The reliability of the presented framework has been confirmed by experts.

In future research, this framework can be expanded and other key indicators can be added and in line with these indicators, new paths can be added to provide computational solutions as well as optimal decisions.

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