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SMART AND SUSTAINABLE SUPPLY CHAIN MANAGEMENT SYSTEM

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Abstract

The sustainable smart supply chain is enabled by advancements in business and information technology that are both environmentally conscious and intelligent. This forward-thinking movement prioritizes additional measures to ensure compliance with social and environmental standards. The Internet of Things (IoT) is a key element of this technology architecture. In this study, we propose a sustainable supply chain framework based on the IoT, consisting of four distinct phases. To demonstrate the intrinsic relationship between data collection processes and industries impacted by environmental sustainability, we constructed a framework by evaluating relevant materials and consulting with experts. This plan has garnered the support of local governments due to its comprehensive approach to making environmentally sustainable decisions throughout the supply chain. As a result of its emphasis on technical solutions, this framework has the potential to make it easier for businesses to develop eco-friendly supply chains.

Keywords: Supply Chain, IoT, ICT, sustainability, Environment friendly

1. INTRODUCTION

A new strategy known as "smart systems" has emerged as a potential solution for achieving economic stability and growth. This strategy considers all possible methods for improving a company's productivity and product quality, with the aim of deepening customer engagement in the design and consumption of the goods and services provided by the company. The ultimate goal of this approach is to foster a more mutually beneficial relationship between the company and its consumers [1]. While the utilization of data in contemporary businesses has brought about new challenges, it has also created new opportunities. Thanks to advancements in information technology, it is now possible to create unique software that can significantly enhance productivity and usefulness. This means that 21st-century businesses can enjoy numerous benefits from these technological advancements [2].

The advancements in technology have led to further advancements, which have created new opportunities for businesses and individuals to interact and combine their resources along the supply chain. However, there are concerns regarding the protection of individual privacy and data security, particularly given the vast array of technologies and systems utilized by businesses in their interactions with individuals [3]. The ubiquitous availability of the Internet and mobile devices has facilitated these interactions, and by analyzing data from a path analysis, individuals can determine the most efficient way to reach their desired destination from their current location [4]. Routing algorithms that are the most advanced perform a real-time analysis of the current traffic conditions. They then use historical data to make probabilistic projections regarding the traffic that might travel along several possible routes. The aim is to select the route with the least amount of traffic disruption. This method ensures that traffic flow is maintained optimally. The Internet of Things (IoT) plays an essential role in creating environmentally friendly organizations [5]. It is a crucial component of an environmentally friendly information and communications technology (ICT) infrastructure since it is a social human technology. The IoT has brought about complex and diverse changes in urban and environmental technology. These changes are a result of the new applications developed for the Internet of Things, which rely heavily on substantial amounts of data [6]. A basic overview of the supply chain process is depicted in Figure 1.

Figure 1: Supply Chain Architecture

The proliferation of the IoT as a computing paradigm and a mechanism for analyzing vast amounts of data is beneficial to intelligent commercial operations and applications in the environmental sector of industrialized nations. The IoT's ability to analyze vast amounts of data enables the convergence of digital and physical infrastructures into a single

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system [7]. This convergence facilitates the development of innovative services and applications that can contribute to the maintenance of ecological balance, showcasing the potential benefits of the Internet of Things. To maximize the efficiency of a system's sensors, devices, applications, and services, it is essential to design the IoT system to consume the least amount of power possible [8]. While the vast amounts of data generated in the area of sustainable smart organizations can be difficult to comprehend, the abundance of data available in various fields is highly valuable.

Urban planners and information technology specialists can contribute to increasing environmental sustainability with their support. Despite the growing research on the Internet of Things and data-related initiatives associated with urban development, the emphasis on commercial applications of IoT has been much lower than that on applications for consumers [9]. As a result, the subject that needs urgent research is "How can big data processing and IoT programs be used to enhance the data landscape of environmentally conscious tech-savvy organizations?" This research aims to raise awareness about the importance of maintaining a reliable supply chain for IoT technology, considering every step of the distribution and sales processes. In the long run, the proliferation of creative solutions founded on the concept of IoT can greatly benefit the environment [10].

This section presents a guideline for conducting a comprehensive inquiry, which is based on the literature and opinions of highly experienced experts and can be found here. The Internet of Things enables the proliferation of vast volumes of data, which is crucial for the functioning of the IoT framework. However, procedures that are less harmful to the natural world should be prioritized. The following section outlines the components that should be included in an efficient and long-term solution for managing supply chains based on the IoT [11]. This method has produced the most favorable outcomes for the environment along the supply chain and can be used to identify appropriate areas for implementation by altering critical variables [12]. To further explore sustainable intelligent systems, researchers can establish analytical frameworks for future studies using the data obtained during the construction and testing of the recommended paradigm.

2. LITERATURE REVIEW

In situations where goods are produced across multiple locations or levels, each step in the production process must be traceable. This not only increases societal awareness but also meets customer demand for transparency and safety. The textile industry, in particular, has a long-standing issue with unequal information and exposure, making it difficult for consumers to authenticate products or make ethical choices. Additionally, stakeholders may struggle to provide important data and risk losing their competitive edge. To address these challenges, this paper proposes a Blockchain-based traceability architecture for the apparel and textile supply chain. The proposed architecture outlines the company's network architecture, dependencies of supply chain partners, and validation criteria for transactions and smart contracts. To demonstrate its effectiveness, the paper presents a use case involving organically grown cotton supply chains that utilize Blockchain technology, custom smart contracts, and transaction regulations. By utilizing

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the Blockchain in various use cases, the paper establishes its utility in recording and verifying supply chain transactions, which can help build technical confidence among supply chain actors. Implementing a Blockchain-based traceability system would give stakeholders a unique opportunity to monitor their supply chains and build reliable public supply chains, thereby enhancing the system [13].

Manufacturers who prioritize technology can boost their productivity and establish a sustainable and eco-friendly supply chain. The concept of a "sustainable smart supply chain" was developed through the integration of smart, eco-friendly industry and IT advancements. Companies are aligning their business practices with societal and environmental expectations by utilizing data to enhance their services. The Internet of Things (IoT) is a crucial aspect of this smart system's technological foundation. To establish an IoT-based sustainable supply chain, this study proposes a framework based on the four-stage architecture of the IoT. This approach streamlines the process of making environmentally conscious and long-term supply chain decisions. It also highlights the correlation between data collection and environmental sustainability. Experts in the supply chain industry have found that this strategy can assist companies in building a more eco-friendly supply chain that emphasizes the use of technology [14].

Supply chain management information has a profound impact on corporate data, a crucial aspect of modern manufacturing and industry. A potential approach to enhancing its intelligence is by implementing advanced technology. The intelligent supply chain employs state-of-the-art technology to enhance operational efficiency, and product quality, and simplify management. The Internet of Things (IoT) is a critical element in developing an information technology infrastructure to create smart and sustainable supply chains. The data generated by IoT devices is voluminous and contributes significantly to productivity and decision-making through big data analysis. The article illustrates how IoT-based big data analytics can design an eco-friendly and intelligent supply chain, using the FMCG industry as a case study. Big data operation and expert analysis form the core of the architecture, based on an IoT deployment strategy. This solution can aid FMCG businesses in making informed decisions about their manufacturing processes [15].

The majority of businesses use supply chain management to ensure profitability and customer satisfaction. A study reveals challenges including insufficient customer service, cost increases, inadequate risk management, and inefficiencies. Cognitive conflict management in supply chains can improve both efficiency and customer service (HCCCMF), reducing labor, energy, and raw material expenses while controlling supply chains. Supply chain behavior analysis enhances customer-supplier relationships and service quality. Analyzing policy matrices avoids operational problems by applying appropriate rates. HCCCMF increases productivity by 94.3%, efficiency by 96.5%, performance by 98.4%, accuracy by 97.8%, and reliability by 95.5% while decreasing trade costs by 15.3% [16].

The food industry is a significant part of the global economy, representing about 10% of the world's GDP or approximately $8 trillion. This value has led to concerns from millions of food industry workers, business owners, and customers worldwide about food safety.

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To ensure the highest quality of food products, it is essential to regularly examine and document environmental indicators that could affect product quality. The Industrial Internet of Things (IIoT), using specialized sensors and the internet, is a potential solution to help prevent and resolve food-related issues. However, the IIoT still faces challenges, such as data storage and sharing information among industry companies. To address these issues, this paper proposes ProChain, an IoT-compatible traceability architecture that prioritizes provenance. By modeling the entire framework on the Raspberry PI 3B IoT device and comparing it to cloud results, ProChain demonstrated the IOTA 2.0 protocol functionalities in the food supply chain, providing openness, transparency, and robust security [17].

The focus of this study is to develop an IoT-based decision alignment system that operates in real-time, aimed at improving supply chain management efficiency (SCPM) through a modular approach. By centralizing decision-making processes involved in turning strategies into operational plans, SCPM can be enhanced. The study recommends incorporating user feedback more in the decision-making process. To achieve this, a system based on the change recognition mechanism, event-driven planning modal, and dynamic decision-alignment mechanism is proposed. Decisions are classified into those made with decision support tools (DSS) and those made without them. A dynamic approach is suggested, utilizing a DSS for lower-level operational decisions and a decision-making-based process (DMBP) for higher-level decisions. The use of SCOR is indicated in this paradigm that is informed by supply chain management, multi-objective approaches, strategic design, and SCOR [18].

In this investigation, we will explore if the application of Blockchain technology leads to advancements in supply chain management. The methodology employed is based on the Fuzzy Analytical Hierarchy Process-based Smart Decision-Making technique, serving as its foundation. This approach emphasizes the importance of prerequisites for utilizing Blockchain technology in supply chain management, placing a higher value on traceability during the application design process. To make informed decisions on whether to adopt Blockchain technology, upper management may refer to the plan developed by the supply chain management department. This department is responsible for creating the plan and ensuring safe transactions and meaningful connections among various Blockchain technology installations in operation [19].

By cleverly utilizing advertising tactics, businesses, designers, and retailers are driving customers and the planet towards unprecedented levels of consumption that pose a threat to both humanity and the environment. This trend is a consequence of the fashion industry's expansion of the global supply chain for fabric and clothing production, which exploits and impoverishes many nations through outdated commercial agreements based on future demand projections. In a world where resources are almost depleted due to the pursuit of new fashion trends and customers seek the best deals, the so-called "New Emerging Markets" have witnessed a dramatic surge in the net sales of established brands like Adidas. However, questions arise regarding the extent to which this profit benefits the fashion industry and local economies. The concept of "value" within the supply chain context requires a more comprehensive perspective, and the industry can achieve this by fostering deeper connections, information exchange, and collaborative efforts through partnerships [20].

Monitoring the effectiveness of ASCs is essential for improving their long-term viability and competitiveness. This study introduces a framework for measuring ASC performance using the Internet of Things (IoT). It also explores how IoT and SCOR work together to enhance SC visibility. The paper presents various KPIs and demonstrates how SCPM can use SCOR to improve sustainability. Using Shannon entropy, weights are assigned to SCPM procedures, and KPIs are sorted using fuzzy TOPSIS and weights at a deeper level. The study identifies "Flexibility" and "Responsiveness" as crucial KPIs for achieving sustainability in ASC's IoT-based SCPM architecture. Only level 2 SCOR measures are considered in this investigation. The findings of the study will benefit managers and specialists across various industries in setting consistent performance criteria for different business process tiers. Moreover, this article provides numerical figures for essential SC strategies, such as responsiveness, asset management, and reliability, thus bridging the gap between SCPM and SC approaches and assisting in the development of a data-driven system for managing ASC projects based on IoT technology [21].

This article conducts an analysis and evaluation of how digital tools have impacted supply chain management, as well as recent research on Supply Chain Management version 4.0 (SCM 4.0). The latest research is reviewed, and a quantitative evaluation is carried out. The article examines the various linkages in the supply chain and analyzes how the introduction of innovative technology affects them. Additionally, it serves as a starting point for future research and applications that shed light on critical aspects of the supply chain transformation process, making it beneficial for both academics and practitioners. Moreover, the article suggests several possible lines of research to gain a deeper understanding of the topic's long-term trajectory. By providing a comprehensive review of relevant previous research, this article presents a new perspective on SCM 4.0. At present, no all-encompassing examination of SC activities considers bibliometric analysis, motivations, barriers, and technology's impact [22].

The environment, the economy, and society are the three components that make up the foundation of a sustainable management philosophy for a corporation. Managing the supply chain in a port necessitates finding solutions to each of these problems. It is very necessary to practice sustainable supply chain management at ports to accomplish the Sustainable Development Goals (SDGs) outlined by the United Nations (SDGs). Despite all of the effort that has been put in, the nature of this link is still unclear. The end goal of the project is to devise a method through which ports may more sustainably manage their supply chains. This will be accomplished through the implementation of such a method. We make use of a method known as the "Dashboard of 5 Ps" to determine whether or not the framework measures would help the achievement of the SDGs (Peace, People, Planet, Partnership, and Prosperity). The findings of the research make it abundantly evident that ports have the potential to influence all of the Sustainable Development Goals (SDGs) in some manner. As ports evaluate how to manage their supply chains in light of economic, social, and environmental considerations, this method may also be beneficial to them as they make those decisions [23].

In recent decades, there has been a significant amount of attention directed at environmental problems and potential solutions to those problems. Green supply chain management ensures that government and corporate policies are effective in greening operations, growing the company's market share, enhancing the company's reputation, and increasing revenue. Green supply chain management also ensures that government and corporate policies are effective in greening supply chains. This article intends to provide a conceptual framework for green supply chain management by concentrating on aspects such as features, classifications, and operations.

During an exhaustive period of study, our team came to a consensus on several green supply chain management models, as well as a collection of green dimensions, classifications, and methods. We present a conceptual framework that is based on data analysis, and it consists of sixty-four environmentally friendly activities, twenty-one different categories, and three environmental components. This paradigm has the potential to contribute to the current body of knowledge because empirical studies frequently only take into account a select number of variables when evaluating green supply chain practices. The following are some conclusions as well as some recommendations for further investigation [24].

Convergent innovation (CI) is used to give an integrated framework of indicators in the current lean, agile, sustainable, and resilient supply chain paradigms. This model is used to manage the supply chain of a dairy, which includes the entire process, beginning with the acquisition of raw materials and ending with the delivery of finished goods to end users. Fresh prospects for commercial innovation, supplier networks, and market structures are created by the CI meta-framework.

This is accomplished through reorienting the decisions made by corporations and actors across society towards the convergence of economic, social, and environmental repercussions. This leads to greater availability of outcomes that have economic value and interest in such results. This framework offers a multi-indicator supply chain management tool that is following lean, agile, sustainable, and resilient supply chain paradigms to supply milk-based required sustenance through convergent innovation. The suggested analytic technique has the potential to be utilized to evaluate and improve the dairy supply chain.

This includes all points along the chain, from milk manufacturing facilities to retail outlets. Because milk production is not subject to quotas, the method that was utilized in this study has the potential to be implemented in the management of farm production as well as transportation to dairy processing facilities [25].

When an organization adopts practices for managing its supply chain that is more environmentally friendly, it can boost both its productivity and its contribution to preserving the natural world (SSCM). This article will offer you a road map to follow to adopt supplier relationship management (SSCM) at one of your vendor partners if you are a manager working for an organization that is wanting to do so. Research in this field is directed by SSCM, best practices in the industry, evaluations of related literature, and the requirements of regional big, medium, and small businesses.

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To learn more about local businesses' efforts to reduce their environmental impact, we traveled to Terre Haute, Indiana (USA). Interviews were conducted with specialists in supply chain management. There is a possibility of encountering both large multinational firms and small, family-run businesses there. These findings were used as the basis for developing a plan for putting SSCM into action. This research has practical significance since the architecture that has been described here may be implemented by any industrial organization, regardless of its size, with just slight modifications [26].

Scholarly publications have published several studies on ecologically responsible supply networks during the past two decades. It is well known that a reliable and environmentally friendly supply chain is necessary to obtain a business advantage. Previous research on sustainable supply chains focused on categorization systems or other coordination approaches rather than a framework. This curriculum focuses on long-term supply chain management strategy. After thorough literature research, adductive reasoning is used to create a strategic framework, which is assessed using grey relational analysis (GRA). The elite interview weighted data shows that several tactics can benefit supply chain members.

The findings also suggest that sustainable supply chains in several sectors may pick the best combination of GRA-enabled techniques to maintain high sustainability performance. As displayed. The previous study lacked a thorough strategy framework, hence the strategic framework is the main contribution. The strategic framework is the fundamental contribution for this reason. A case study demonstrated the method's framework [27].

The economic and social values in the global supply chain have been significantly influenced as a result of COVID-19. In the event of a widespread pandemic, it will be extremely challenging to accomplish the Sustainable Development Goals by the year 2030. This study investigates how the COVID epidemic has impacted supply chains, as well as how sustainable finance has contributed to the establishment of these chains. Based on our analysis, we were able to determine which modifications to the supply chain were necessary to ensure that it would be successful.

In this case study of the food industry, MCDM techniques were used to prioritize several elements. The fundamental and additional requirements for attaining sustainable supply chain financing are outlined in the following paragraphs. This research contributes to the growing body of literature on sustainable supply chains by demonstrating how financial resources may play a pivotal role in accomplishing sustainable supply chain objectives, which in turn contribute to broader sustainable development goals. This research also contributes to the growing body of literature on sustainable supply chains. According to the results of this research shown in Table 1, organizations in every industry should place a greater emphasis on preserving social principles than any other consideration [28].

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Table 1: Comparative Analysis

Ref.	Real-time tracking	Automated inventory control	Predictive analytics	Integration with other systems	Blockchain technology	Cost Effective	Scalability	User-friendly interface	Mobile compatibility
[13]	Yes	No	Yes	No	No	No	No	No	No
[14]	No	No	Yes	No	No	No	No	Yes	No
[15]	No	No	No	No	Yes	Yes	No	No	Yes
[16]	No	No	No	No	No	No	No	No	No
[17]	Yes	No	No	No	No	No	No	No	No
[18]	Yes	No	No	Yes	No	No	Yes	Yes	No
[19]	No	Yes	Yes	No	No	No	No	No	No
[20]	No	Yes	Yes	No	No	No	No	No	Yes
[21]	No	Yes	No	No	No	Yes	Yes	No	No
[22]	No	Yes	No	No	No	No	No	No	No
[23]	No	No	No	No	Yes	Yes	No	No	Yes
[24]	No	No	No	No	No	No	No	No	No
[25]	No	No	No	No	Yes	Yes	No	No	Yes
[26]	No	Yes	Yes	No	No	No	No	No	Yes
[27]	No	Yes	No	No	No	Yes	Yes	No	No
[28]	No	Yes	No	No	No	No	No	No	No

3. METHODOLOGY

The research approach selected for this study was qualitative content analysis, which was chosen because it provides a realistic portrayal of quantitative data by uncovering and explaining the indicators and aspects that are effective in IoT-based smart supply chain procedures [29]. To gather data for this investigation, relevant literature was reviewed and opinions were solicited from field specialists who were involved in IT and supply chain management industries.

In-depth interviews were conducted with these specialists, starting with the question "What are the most distinctive characteristics of a smart supply chain based on the Internet of Things [30] ?" The responses were used to formulate subsequent questions. To ensure the accuracy of the data, notes were taken during interviews, and experts were granted access to the data and analysis findings to provide their expert comments. Additionally, specialists reviewed some of the final results to ensure proper interpretation. To analyze the interview data, a technique called "theme analysis" was utilized, which involves immersing oneself in the data, organizing and summarizing it, and focusing on how it should be understood [31].

Big data analytics, IoT, and ICT are the key components of sustainable and intelligent supply chains. This approach examines the entire supply chain, from procurement to

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distribution, to identify energy-efficient and environmentally friendly solutions. The outcome of this process is the creation of various applications, data processing tools, sensor technologies, and sustainable computing models [32].

The smart supply chain is a broad concept that includes a network of physical, social, and economic infrastructures that sustainably focus on important areas such as smart transportation, smart economy, smart environment, smart people, smart management, and smart activities. By adopting cutting-edge technologies and innovative operational procedures, companies can improve their efficiency and stay competitive in areas such as smart economy, people, environment, activities, and management [33].

The IoT supply chain facilitates the sharing of information among people, processes, and devices, leading to the generation of massive amounts of data. Currently, the terms "smart supply chain" and "sustainable supply chain" are not widely used. Innovative supply chains consider economic, social, and environmental factors to improve a company's operations, services, and competitiveness to meet current and future demands. However, big data is complex, unique, and constantly increasing, making typical analytical methods ineffective.

Big data processing relies on a range of analytic methods (regression, clustering, classification, and other algorithms), techniques (statistical analysis, machine learning, data mining, etc.), and technology to rapidly extract insights from massive datasets [34].

Big data analytics requires sophisticated software and database management systems to process vast amounts of data in a smart and sustainable supply chain, utilizing powerful computers. Research has recently turned to how the Internet of Things (IoT) and big data can drive economic growth, with a new focus on establishing sustainable companies [35]. This involves IoT-based supply chains that prioritize eco-friendly practices and concrete activities, addressing environmental sustainability issues caused by ICT inequities. To achieve this, organizations need to integrate their digital and physical infrastructures while considering all available information.

Various studies have examined conceptual frameworks for the IoT and its applications, demonstrating how it can increase supply chain intelligence and environmental benefits [36]. Responsible enterprises must manage complex physical and environmental systems to minimize environmental damage. Identifying the most crucial indicators is vital for integrating the IoT into a sustainable supply chain.

Table 2 provides examples of Key Performance Indicators (KPIs) that may apply to firms. Highlighted factors impacting key indicators and high-quality, efficient use of IoT data contribute to the development of IoT-based sustainable supply chains [37] [38] [39].

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Table 2: Performance Indicators

PI	Description
Return rate	The percentage of orders that are returned by customers
Supplier lead time	The time it takes for a supplier to deliver raw materials or components after an order is placed
Order processing time	The time it takes for an order to be processed and prepared for shipping
Capacity utilization	The percentage of production capacity that is being used
Cost of goods sold	The cost of producing and delivering to customers
Environmental impact	The environmental impact of the supply chain, including sustainable house gas emissions and waste generation
Customer satisfaction	A measure of how satisfied customers are with the supply chain, based on surveys or other feedback mechanisms
Supply chain visibility	The ability to track products and materials throughout the supply chain, providing real-time updates on their location and status
Forecast accuracy	The accuracy of forecasts for demand, production, and inventory levels
Employee productivity	A measure of the productivity of employees involved in the supply chain, such as warehouse workers and logistics staff

This framework was developed by considering the four-layer IoT implementation model, which includes data collecting, data cleansing and analysis, data processing, and data utilization. The process involves gathering, storing, processing, evaluating, integrating, and communicating vast volumes of data across the supply chain while focusing on key indicators for sustainability. To increase one's level of knowledge, various procedures such as selection, preprocessing, modification, exploration, interpretation, and assessment can be employed [40]. The process of data mining consists of several steps, including information comprehension, data preparation, modeling, evaluation, and application. Both of these approaches to environmental sustainability prioritize acquiring new information and making better use of available resources. The gathered information can be utilized in decision-support, decision-making, automated decision-making, and various other contexts. Four essential information functions, including control, automation, optimization, and management, must be considered when making strategic and tactical decisions [41].

The presented framework aims to integrate cloud- and fog-based Internet of Things technology into a data-intensive "Sustainable smart chain" that includes sensors, data storage and retrieval facilities, information processing platforms, and cloud/fog computing models. The system aims to reveal the relationship between data intake, Internet of Things-based smart analytics, and supply chain position. While other IoT-based smart city frameworks exist, this particular framework prioritizes sustainability and environmental friendliness, with widespread implementation of smart supply chains in mind. To gather, analyze, preprocess, and translate sensor data from various subdomains along the supply chain, the system employs model construction strategies based on data mining and machine learning. This aids manufacturing units, planning, and other tasks by automating and assisting decision-making through patterns, pattern recognition, and correlations. Overall, the framework prioritizes sustainability while optimizing supply chain performance metrics [42].

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By employing cognitive analysis, we can extract the core aspects of a sustainable supply chain framework that emphasizes the beneficial impact of the Internet of Things and extensive data processing on the environment. Within the supply chain, sensor technologies, computational models, data-driven applications, and data processing systems are all viable. The key elements of this structure are illustrated in the Figure 2 [43].

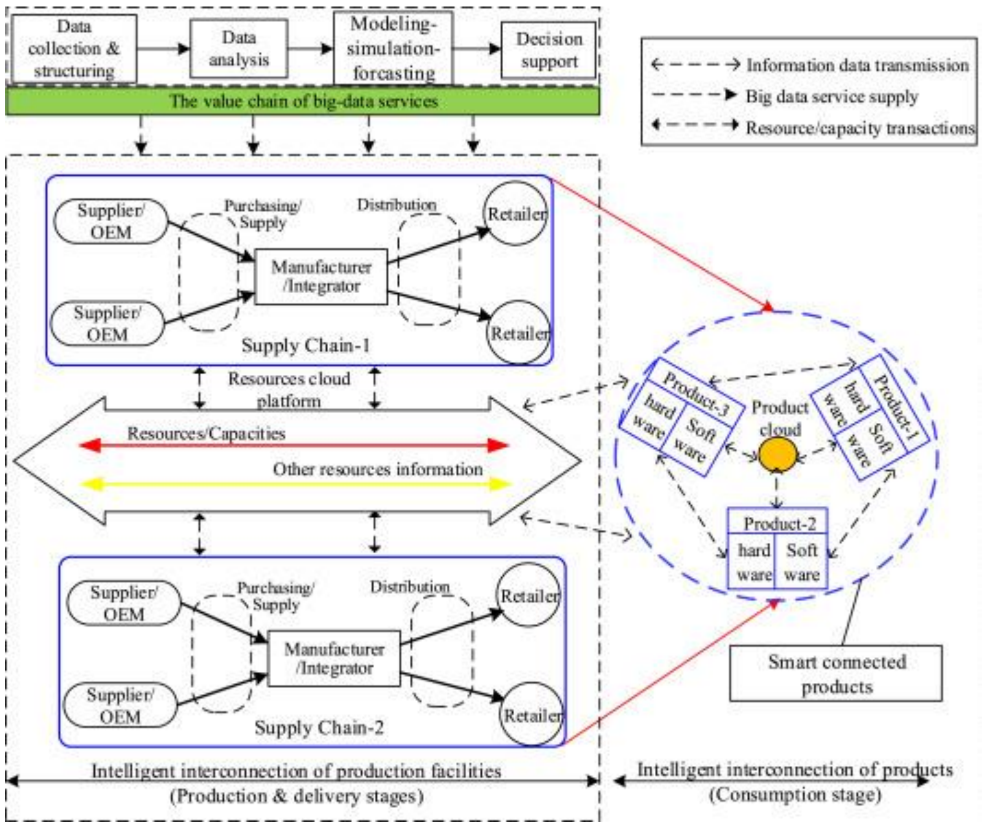

Figure 2: IoT-Based Sustainable Supply Chain Framework

Devices such as sensors, smartphones, and tablets are linked directly to the supply chain's data sources, allowing for greater sustainability through the use of these technologies, as well as other physical and virtual transactions. Sensor data can be gathered and stored in various ways, with high volume and velocity. Their distinctiveness and widespread origins further underscore this [44] [45].

As a result of their substantial size, the analysis of these datasets requires expert knowledge. By utilizing this information and KPIs, the supply chain can more easily focus on and enhance the environmental sustainability factors that are most important. These benefits are currently being realized in several areas, such as traffic management, fuel monitoring and optimization, decreased pollution from industrial machinery use, and efficient energy usage. Achieving this objective necessitates specific big data analysis techniques, such as computing in the fog and the cloud, which have gained traction in recent years. We increasingly depend on distributed and networked computation performed on data that has been retrieved and refined, facilitating the optimization of

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processes, system performance, and ultimately decision-making. The new framework's ability to provide a clear implementation plan for IoT-based supply chains that prioritizes sustainable development and identifies a proven implementation path is one of its most valuable features. The reliable connection between data entry channels and the location where they have an impact ensures optimal performance at the right time [46] [47].

4. EVALUATION

In collaboration with a different type of retailers, the team conducted survey on a high-tech and environmentally friendly system to manage the supply chain. The primary objective was to ensure customers received fresh products on time and reduce waste and carbon emissions. The investigation covered the entire supply chain, from manufacturing to the business end. To achieve the goal, the team established a smart supply chain management system with real-time monitoring, automated inventory management, predictive analysis, and IoT devices. Additionally, the team implemented eco-friendly practices such as reducing product or raw material waste, updating transportation routes to lower emissions, and using sustainable packaging.

5. RESULTS AND DISCUSSION

The results of the evaluations are given in the below Tables 3, 4, and 5.

Table 3: Reduction in Waste

Metric	Before Implementation	After Implementation	% Reduction
Unsold Inventory	25,000 kg	10,000 kg	60%
Spoilage	12,000 kg	5,000 kg	58%
Returns	2,500 kg	1,000 kg	60%
Total Food Waste	39,500 kg	16,000 kg	59%

Table 4: Reduction in Carbon Emission

Metric	Before Implementation	After Implementation	% Reduction
Miles Driven per Week	10,000	7,000	30%
Fuel Consumption per Week	1,200 Gallons	800 Gallons	33%
C02 Emissions per Week	11,480 kg	7,656 kg	33%

Table 5: Cost Effectiveness

Metric	Before Implementation	After Implementation	% Reduction
Labor Costs	$200,000	$150,000	25 %
Transportation Costs	$300,000	$225,000	25 %
Packaging Costs	$75,000	$65,000	13 %
Total Cost Savings	$575,000	$440,000	24 %

According to the data, there has been a significant decrease in waste, and prices carbon emissions. This reduction in carbon emissions and waste can be attributed to the implementation of advanced technologies such as real-time tracking, predictive analytics, automated inventory control, and route optimization. In addition, costs have been reduced through the reduction of food waste, the use of environmentally friendly packaging, and the optimization of transportation routes. Overall, the supply chain management system

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has become more efficient, resulting in lower levels of food waste, reduced costs, and decreased carbon emissions, while still ensuring timely delivery of fresh products to customers.

6. CONCLUSION

The Internet of Things (IoT) has gained attention from environmentally conscious businesses for its effectiveness. To fully utilize IoT and big data analytics, companies need to optimize their information environment by integrating applicable frameworks to provide better goods and services. IoT and big data analytics can also provide insights about the natural world for both academia and industry. The goal of this study is to examine and discuss data related to Big Data applications for environmental sustainability, data processing platforms, and computing models for a sustainable smart supply chain. The study presents a multi-tiered approach to building an IoT-based sustainable supply chain, highlighting the causal relationship between environmental sustainability data and their impacts. The framework provides key locations and step-by-step guidance for implementing an IoT-based sustainable supply chain, which has been rigorously tested by industry professionals. Future improvements may involve incorporating more indicators, alternative routes that align with current indicators, computational solutions, and other viable alternatives.

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