Carbon Footprint Modelling and Circular Economy Optimisation: AI-Driven Frameworks for Environmental Sustainability in Supply Chain Management

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1. Introduction

In the backdrop of the global climate debate, the world is looking to achieve socio-economic objectives through a change in the existing way businesses are managed. Sustainable supply chain practices that address the socio-economic and environmental objectives of businesses have become central. There is a strong call for sustainability from consumers, regulators, stakeholders, and activist shareholders. However, it is equally compelling that the practices must be in line with business objectives, be easy to implement, and maximize the benefit to business. It is also compelling that AI will be a game changer in achieving these practices. It can help overcome the existing challenges in the development and implementation of sustainable supply chain management by integrating various modules such as forecasting, scheduling, inventory management, and production planning, among others. This paper aims to present AI as a tool for enhancing sustainable practices in the supply chain and to provide practitioners, scholars, and information systems professionals with insights into the ways AI can and does change sustainable practices in the supply chain. The objectives of the paper are twofold: to present sustainability in supply chain practices and its benefits, and to present AI and AI-driven smart services and outline their role in each dimension of the supply chain that, when implemented, will lead to sustainability. The study concludes that procurement schedules, accurate demand forecasts, and well-managed supply chains are features that are miles ahead in being sustainable. Smart services driven by AI can deliver all.

1.1. Background and Significance of Sustainable Supply Chain Practices

Sustainable supply chain practices (SSCPs) are continually evolving. The idea of reducing the environmental impacts of a company's operations by integrating requirements for procurement, operations, warehousing, distribution, freight, and logistics continues to be developed and improved upon. Sustainable supply chain practices can be seen in the context of historical progression to a more comprehensive system of globalization and local interconnectedness, respect for the environment, and concern for increasingly longer-lasting impacts of industrial production on the environment.

Three main aspects have driven the development of the sustainability issue in the supply chain. These are: the environmental issue; the economic issue; and corporate social responsibility (CSR)/public relations. Companies are feeling pressure to create sustainable practices from business-to-business (B2B), business-to-consumer (B2C), and government entities for reflection of the increasing public concern for environmentally healthy and ethical business practices. Finally, a brief theory on innovation, especially in the new era of integrated technological development and social innovation, will be introduced and explained. An example is the application of an artificial intelligence approach in greater detail.

2. Foundations of AI in Supply Chain Management

Artificial intelligence (AI) is commonly associated with cutting-edge technologies such as self-learning algorithms and computer vision. More specifically, supported by machine or deep learning, AI-driven applications have become routine in collaborative robots, digital assistants, and recommendation systems. At its core, AI is different from machine learning (ML) or deep learning (DL). While these concepts have gradually become more important, especially in supply chain management (SCM), AI broadly refers to tools and techniques that allow machines to mimic some forms of human intelligence. With rapid advancements in computing resources and capabilities of AI systems, its application scope has increased and evolved. The availability of such technology goes hand in hand with the widespread integration of AI-driven solutions. On the other hand, the question of where, how, and why AI should be integrated into SCM has not yet been answered satisfactorily. Foundational elements for applying AI-driven solutions in the field of practice, specifically SCM, are fundamental to grasp in this context. To do so, the understanding of AI should be extended to a system containing data processing and decision-making, cumulatively realizing automated transformation and managerial processes. From a supply chain perspective, AI technologies are central to a variety of SCM areas. One particular use of AI is the intelligent prediction of customer purchasing behavior, to mention one use case. AI provides input and support in the automation and planning of products, control over inventories, as well as the ordering process. Moreover, predictive analytics are facilitated by AI-driven technologies allowing for operation, inventory, and production-dependent analysis. Needed data for this process are commonly abundant in many firms and industries, coming from various internal and external sources. Understanding these foundational components of AI in supply chain operations assists in realizing the full potential of AI technology in the area of sustainable supply chain practices, including optimization and risk assessment.

2.1. Overview of AI and Machine Learning

AI and machine learning remain elusive concepts for many supply chain managers. The subjective understanding of AI creates a significant barrier to its adoption. Therefore, before progressing the discussion, it is essential to clarify these concepts. AI is an overarching concept that encompasses the programming, learning, and problem-solving capabilities of a computer. It is an umbrella under which machine learning falls. Machine learning refers to the process by which a computer is taught to learn based on the data it is presented, often using algorithms developed on inputs from human expertise and experience. There are two main types of learning processes: supervised learning, by which a computer teaches itself according to detailed human input, and unsupervised learning, where the system identifies patterns in a wide variety of data. In meaning, machine learning refers to the development of devices that can mimic human cognitive functions, such as learning and problem-solving.

Machine learning techniques such as clustering and classification, dimensionality reduction, and prediction regression are utilized to conduct complex data analyses. Clustering and classification processes are used to group data points in a dataset based on similarities or to learn decisions based on example inputs and outputs. Dimensionality reduction, as the name suggests, summarizes datasets with an excessive number of variables. When predicting a set of factors according to historical data, scientists give degrees of risk; the outcomes are all quantified by the probability of the result occurring. This risk evaluation is termed prediction regression. Analysts and data scientists can determine important patterns, which enables them to make forecasts and recommendations towards corporate use as a result of these tests in a research scenario.

Data are the building blocks of such learning-based systems. High volumes of data, as well as feasible infrastructure and analytics to transform the data into meaningful information, are needed to effectively utilize this capability. Artificial Intelligence (AI) has recently been given a greater profile in the field of supply chain management. Technological advances have expanded AI tools for supply chain use, making these tools more affordable and accessible to companies of varying sizes and volumes. Neural networks, or computer-based systems based on human brain functionality, are propelling this trend forward. Within the industry, there are numerous applications of machine learning. In shifting through the large amounts of information they obtain, internet-based companies recognize demand patterns, and financial services firms differentiate between their customers and fraudulent transactions. Other applications include real-time product pricing, workforce scheduling, risk management, enhancing store and micro-targeting promotions, supplier evaluation, predictive maintenance, inventory planning, logistics, and demand forecasting. It is therefore clear that progress in the capacity and speed of machine learning algorithms considerably improves decision support and operational efficiency. More sophisticated marketing models, experience economies, and improved contact with efficient procurement, including improvements in predictive procurement and demand levels, can yield feasible benefits from learning systems. Furthermore, it can grant organizations a profound understanding of the data they monitor in corporate social responsibility and sustainable supply chain management by exposing hidden market-level and product-level linkages. Before using AI for supply chain practices, a word of prudence is needed: ethical and social concerns. AI-enabled services are competing in a broader context to protect personal privacy, knowledge ownership, and conversion through access to business intelligence and services. Any supply chain IT initiative can benefit from an understanding of the wider IT initiative, or else the effects of the AI programs on the broader IT initiative.

2.2. Applications of AI in Supply Chain Management

AI is receiving global attention for how it can help tackle efficiency and environmental challenges that programming and development have failed to address. Research in the logistics and supply chain arena has a long tradition of operations research and optimization, mostly dealing with small and medium-sized instances of well-constrained, defined problems. AI has the potential to transform this context by delivering large organizations' multi-parametric optimization, operations research, and flexibility to respond to changing demands and supply chain conditions subject to higher levels of constraints, which we address in the next several subsections. Current supply chain management practices can be enriched with the most advanced AI technologies. This can support, for example, optimal decision-making in fulfilling demand forecasting and planning, reducing overstocking and understocking during inventory control. AI technologies can also assist in supplier selection and negotiation processes to reduce the costs of setting up partnerships for implementing sustainable supply chains. AI-based optimization can address and improve logistics and better operate fleets with large numbers of vehicles covering multiple locations. Large airlines, automobile, and telecommunications companies are reaping the benefits of using AI techniques in complex network and demand forecasting where routes may have to be altered on the spot. Predictive maintenance can save considerable downtime and revenue loss. It can also mitigate risk in the supply chains due to potential machinery breakdown. AI-driven systems are supporting the increased use of connected machinery and vehicles, and consequently real-time data, to support agile planning and execution. The classification and analysis of risks via historical data and scenarios from internal and external operations can improve risk management. These require substantial streaming data engines and at least predictive and descriptive analytics to detect patterns, correlations, provide alerts, and push potential mitigation strategies in time-critical delivery operations. To date, few large organizations have embraced these AI technologies at scale. There are leaders who have identified new services to launch to make money from, but they did not identify how to implement AI across existing and new systems at large. Reasons for this arise from the subtle complexities and challenges in managing data privacy and security, and the need for strong, stable, and sophisticated systems architecture to run AI. Moreover, big data and the rich history that can be used to implement and visualize optimization in the supply chain are pains for AI utilization. These need extreme curation efforts before the AI can be used and then with a high degree of customization.

3. Environmental Impact of Supply Chains

The United Nations Sustainable Development Goals suggest that our focus should be more on sustainable development. The term sustainability refers to having an economy, society, and environment that can be maintained into the future. A sustainable supply chain can be a sustainable competitive advantage, not only regarding economic impact but also strategically and environmentally. Each day we learn about the efforts different organizations are making towards sustainability in their supply chain operations. Traditional supply chain practices have led to numerous environmental problems such as high carbon, water, and energy footprints, along with waste generation and resource depletion.

The food industry is a significant contributor and has diverse negative impacts on the ecosystem. Similarly, e-commerce has an increasing demand for online retail or trade that affects our environment. Furthermore, the impacts on the environment can spread across the globe. The majority of greenhouse gases are emitted from the developed world, which is home to numerous production units that move the final products into the developing world to be consumed, which in turn results in melting glaciers and increasing sea levels. When sustainability in a supply chain is not addressed because the supply chain practices are just compliant with prevailing rules and regulations, it significantly contributes to problems that threaten the ability of the planet to sustain generations of all species today and in the future. The consequences of unsustainable supply chain practices have horrifying implications for the global economy that affect human living conditions globally in terms of scarcity, climate change, and biodiversity loss. Some have identified practical solutions to supply chain-related environmental challenges.

For example, some suggest businesses should balance profits and ecological impacts and establish operational principles, such as upholding environmental laws voluntarily, going beyond compliance, considering environmental aspects when packaging goods, selling goods that minimize environmental impacts, or leading sustainable environmental practices. Others in the logistics and supply chain sector suggest a mechatronics-based approach to disposing of goods, dematerializing goods, and developing a preference for services. Some suggestions point to sourcing and ordering with life cycle consequences and considering environmental consequences, such as reducing inventory to save both money and reduce the size of a firm's environmental footprint. Several researchers evaluating environmental paradigms from a green logistics perspective have discovered the implementation of holistic, integrated, and mutually beneficial solutions. However, some limitations still remain.

3.1. Key Environmental Challenges in Supply Chains

As an initiator of sustainability in supply chains, understanding the existing challenges and the context of sustainable supply chains is of prime importance. In this section, our aim is to understand the factors that compel supply chains to adopt environmentally and economically sustainable operations. The basic structure of global supply chains is overproduction followed by distribution and consumption of goods across the globe. This results in significant environmental impacts due to high levels of emissions from vehicles, reduced energy efficiency, and so on. Greenhouse gases are released not only during the actual transportation but also throughout the entire supply chain process, including production, distribution, delivery, and storage, which collectively makes supply chains one of the major contributors to this.

Furthermore, increasing levels of waste across the world are directly related to inefficient supply chain processes, such as overproduction of goods that are not sold, which in most cases are disposed of, mostly through environmentally harmful methods like landfills and burning. Moreover, the use of scarce resources also continues in a similar manner where supply chains have no built-in facilities to recoup the materials and reuse them. Hence, orchestrating supply chains in such an unsustainable manner not only impacts the world but also local communities due to high levels of traffic movements, use of local roads, and such physical characteristics of buildings linked to supply chains in the vicinity. Organizations are increasingly realizing that consumer behavior is a sensitive topic within sustainability and is likely to result in high levels of pollution or environmental damage due to consumption. Consumers are the end users of goods, and hence their changing purchasing behavior directly reflects additional materials being processed, transported, used, and subsequently disposed of, with a resulting environmental impact. For example, a fashion brand sells 500 million dresses each year, which ultimately leads to approximately 975 billion liters of water being used in the process. Hence, organizations are now coming forward to use environmental labeling with stakeholder investors to build partnerships and react to consumer concerns regarding sustainability and traceability issues to position green products. These factors percolate to a variety of business-related drivers within a sustainable supply chain, such as influences in the form of reducing the use of scarce resources in industries and adopting eco-efficient production processes within industries to position themselves in niche markets. All these factors are defining the context of sustainable supply chains. Hence, supply chains, by their inherent nature, are directly impacting the world and local communities through high levels of emissions, traffic, and associated environmental damage. This has catapulted the need to talk about the legal and moral responsibilities of supply chains and how these negative factors can be mitigated. Recommendations for the reduction of waste and current overreliance on primary materials also abound, leading us to declare that there have been calls to action for companies to operate sustainably for more than four decades now.

3.2. Current Approaches and Limitations in Addressing Environmental Impact

Several strategies can be adopted at the operations level in order to mitigate the environmental effect of supply chains and logistics systems, including transport and inventory management. These include green logistics practices, procurement strategies, and operational strategies such as 'green' warehousing and customer demand modulation, as well as the reduction in reverse logistics activities by eco-designing closed-loop supply chains. While all contribute to managing the environmental impact of supply chains, there are also disadvantages to a single focus on specific operational strategies. Notably, the uncertainty involved in reverse logistics operations can make cost-effective carbon optimization difficult. For example, inventory management in closed-loop supply chains, where return quantities of the product are not known, is subject to error, while transport networks that are less well controlled must make increased use of road vehicles to move products between warehouses or distribution centers. Greater levels of coordination of transport and inventory management activities, including joint optimization of vehicle routing, and location and inventory profile policies, must therefore be included in closed-loop supply chain modeling approaches.

Despite the above strategies, there may be barriers to innovation and the reduction of environmental effects in the logistics industry due to technological and information constraints, market power concerns, supply-side constraints, and lack of strategic drivers. Additionally, we find that international trade needs to be managed in order to reduce or mitigate the associated emissions across small and medium enterprises. For example, small and medium enterprises can use biofuel alongside other high sustainability fuel logistics in order to reduce the environmental impacts related to waste paper export. Our review also provides policy suggestions that can encourage the alignment across small and medium enterprises. Overall, our comprehensive review is an attempt to highlight the importance of systemic thinking when dealing with the issue of environmental impacts from global supply chains. Our results also raise the issue of how global supply chains can become not just more resilient but also sustainable. Our results also emphasize the need for more innovative research solutions to simultaneously examine a wider range of environmental, social, and economic drivers with a view to making planning solutions more desirable and implementable.

4. Machine Learning Techniques for Sustainable Supply Chains

An array of machine learning techniques represents abundant riches that can effectively transform today's supply chain practices into those that are sustainable. Typically, companies are seeking predominantly soft benefits, which are subtly influential. Predictive analytics optimizes the demand forecast, which in turn makes the entire chain more effective as minimum stock is being held and less waste is being produced. Learning methods can thoroughly detect patterns and offer insights in predicting demand. Under normal circumstances, the use of heuristics and the judgment of the decentralized agents would benefit from the modeling of the dynamic elements of the supply chain. When embedded in real-time data streams and a decision-making process, machine learning can also be used to model an optimization algorithm like a route planner such that such a plan can minimize transport emissions dynamically as circumstances in the supply chain change.

One can distinguish two main areas of application of machine learning in demand chains: one, using machine learning to perform predictive analytics of demand, and two, using the predictive base data to calculate and plan alternative dynamic strategies for the supply chain. To provide a clearer insight, two related investigations on this subject are presented here to clarify in more depth the predictions and alternative strategies in an integration with real-time data. Both manuscripts utilize machine learning. Matching and selecting sustainable alternatives has focused on exploring the impact of a technology that reduces emissions. They further discuss the case of one e-grocer in

Greece and the ways and means they are deployed to support the ethical consumers who give quick service and delay the packing, forbidding the smallest possible packaging to promote green deliveries in the environment.

4.1. Predictive Analytics for Demand Forecasting

Research has shown that machine learning for predictive analytics has become one of the basic approaches most commonly used to enhance demand forecasting capabilities within supply chains. Predictive analytics analyzes specific data patterns using machine learning algorithms to create future estimations on that data. Demands are predicted based on historical data, for instance. As the organization progresses, it carefully analyzes search trends, peer opinions, news reports, social media, market trends, and demographics. Predicting the essentials is one of the most significant inputs to good planning and design. It allows manufacturers and retailers to plan and deliver products and services more efficiently, minimizes the depletion of limited resources, reduces the likelihood of product overproduction, and eliminates stockouts. For many years now, a number of models have been deployed in various industries to make their forecasting more reliable, efficient, and effective. The performance level of such models varies depending on their capability, the availability of input data, the specific industry in question, and their configuration and settings. In real-world applications, leading-edge companies in logistics and supply chain industries have begun adopting advanced predictive analytics for supply chain and demand planning. Using advanced, predictive, and prescriptive analytical forecasting tools for demand and dependency modeling, companies have saved millions. These predictive models are mainly built on machine learning methods such as Naive Bayes, Support Vector Machine, Random Forest, and Stochastic Gradient Descent Regressor. Advanced automation in predictive analytics and business forecasting will create new jobs, specifically in demand forecasting that will improve profitability and efficiency. Many companies' challenge is to gather and combine data from various tools and databases while ensuring accuracy and immediate data insights. Although there is no shortage of data, it is a serious problem to get high-quality data. Over the last few years, significant advances in artificial intelligence, particularly in predictive analytics, have led to the development of systems capable of making highly precise predictions. In an effort to identify reliability and recognize various dependencies, data-driven standards and practices which are needed for this field of research, traditional forecasting methods have also been used. Several other forecasting models, such as autoregressive integrated moving average, exponential smoothing, linear regression, and long-short-term memory for recurrent neural networks forecasting, have also been proposed. Ongoing development, such as machine learning and predictive analytics, will provide a robust platform for AI to deliver improved accuracy and scalability in the predictive analytics field. The emphasis on machine learning and predictive analysis, however, is highly relevant in this AI area, particularly in the supply chain and demand planning.

4.2. Optimization Algorithms for Route Planning and Inventory Management

Researchers have explored the use of optimization algorithms in different areas of sustainable supply chain management. Main applications include route planning and inventory management. Route planning has huge potential to increase the overall logistic efficiency in delivering cargo. The optimization algorithm can help select the best route that minimizes the traveled distance of vehicles. Optimization of routes has been observed in several studies, including various approaches to delivery scheduling and vehicle routing problems. Modeling of route planning has been done in different forms that can be generally seen in time-dependent heterogeneous fleet, integrated production and distribution systems, stochastic vehicle routing problems with emissions, capacity and time windows, and dynamic vehicle routing with time and emission dependent travel times.

Optimization algorithms can also optimize inventory management, which can help in reducing overconsumption and overpurchased products. In particular, inventory acts as a buffer between different entities in supply chains. In the supply chains, the optimization of inventory helps reduce obsolete components and energies to lessen the wastage of resources. In addition, the management optimization effect of the algorithm is better with the inventory management modeled in the following areas: reverse logistics stocking decisions, multi-time period stochastic production scheduling with inventory management, and macro-level logistic system. Similarly, the effect of inventory management optimization algorithms with less energy usage can be seen in reducing energy usage in an automated warehouse by improved inventory management, coordinated production, and inventory management for perishable products. Few case studies in sustainable supply chains show that route optimization using optimization algorithms helps reduce overall costs and energy expenditure. For the inventory model in a supply chain, a study on a two-stage supply chain has shown that the technique is found to be highly effective in optimization. A similar observation can be seen with a company in Denmark, where the application of global greening and logistic services has doubled the turnover in two years. Overall, the coordinated production reduction logistics solution shows high potential in energy reduction.

5. Case Studies and Best Practices

Case studies that present real-world examples and evidence are prime illustrations to showcase how, why, and under what conditions AI can be used for sustainable practices in supply chains. This section interweaves detailed case studies including project overview, AI system description, implementation, and outcome with best practices and lessons learned. In so doing, we show that some effects, especially the cost savings, can be quantified and appraised, in addition to a subsequent green dividend from AI integration. The cases in this section offer valuable suggestions for how partnerships with third-party suppliers, regulators, and an ethos of prior risk minimization and values-driven supply chain management, both within and beyond a company, were successful. The first three case studies in this section represent industries using AI in experimentation, field, and factory-level implementation, respectively. Security concerns and a changing ambient AI landscape represent a common setback that must be strategically approached. The associated pitfalls underline the importance for partners in supply chain management to adapt AI strategies, as well as the potential for those companies that do. The cases further illustrate technology transferability and the applicability of AI to a range of industries. The cases are not too large or too expensive and therefore are replicable.

5.1. Successful Implementation of AI in Real-world Supply Chains

Though some strategies work in the lab, it is difficult and not always the best idea in practice to implement some of them in real supply chains without further reworking them. In this section, we will outline some cases with examples of successful AI implementation in real-world supply chains with a known outcome. Some process details and strategies taken are provided in some cases. We focus only on the results that can be quantified, either from the innovation outcome or explicitly stated in the final paper that summarizes the implementation results. The results can be stated as either the percentage of error reduction from the machine learning model, or the rate of increase in key performance parameters that happen during deployment, such as reduction in transportation cost, reduction in human workload, efficiency, and so on. We notice that the implementation of AI in real supply chains can take different forms, such as redesign or replacement of strategies or process re-engineering to improve efficiency or sustainability. The following studies show the implementation of AI and machine learning in different business fields, such as retail, logistics, distribution centers, inventory management, and emergency response.

• Implemented a decision-support system based on AI for the sustainable supply chain and allocating products in several distribution centers. Using a specific platform, they integrated a model with the system designed to assign CO2 labels to the products, providing environmental information to the final customer. They implemented the study in a company that operates in the do-it-yourself market and has one main distribution center in northern Italy, an automated unit that prepares orders from the warehouse to the store, and more than 1,360 stores in the region. The result underlines a 73% reduction in environmental impacts by rearranging the stock in the distribution center. • Explored the required conversation held by all stakeholders when deploying AI to redefine the logistics operation process. A biotech company wanted to find out the most efficient and sustainable last mile delivery option for each delivery to hospitals. The company has been using a specific enterprise resource planning system for over a decade, and they could not get it to deal with the throughput of hospital material in real-time. Needed: a revised supply chain strategy based on a new IT solution; to scale up the most practical real-time data capture and machine learning systems. Uses Blockchain to improve trust and sustainability in supply value chains.

5.2. Lessons Learned and Recommendations for Future Implementations

Lessons Learned and Recommendations for Future Implementations

Given the insights from the examples of the case study presented in the three previous sections, this subsection provides some lessons learned and practical insights for future initiatives that aim to leverage AI for the sustainability of supply chain operations while focusing the analysis particularly on the role of AI in developing sustainable supply chain practices.

Strategy and Objectives. As with any technology, it is important to have a clear strategy and objectives in place. The AI strategy should start by identifying the 'low hanging fruit' where it can help improve decision-making, increase efficiency, and support employees in their tasks.

Challenges and Recommendations. Overcoming resistance to change and the mindset change are among the main challenges. The process should include change and stakeholder management in the vision of a co-creation of the systems. Additionally, special attention should be given to data integration difficulties. Organizations could consider starting to build algorithms that learn 'as they go', which require large-scale integration, rather than taking a big bang approach to AI deployment.

The Issue of Explainability and Conducting an Evaluation. A crucial factor to aid universal acceptance lies in the ability of AI applications to produce results and insights that are easily explainable. Consequently, it is critical to supply reasoning for AI-based decisions, for example, by explaining the weights of features or the influence of single decisions.

The Journey is as Important as the Results. Despite the much-lauded benefits, the reality is that organizations never reach a point where they make fantastic decisions all the time using machine learning. It is important to enable users and management to visualize this improvement in decision-making in comparison with more static statistical algorithms that do not learn from newly available data. Those services ask 'what changed'. Applied to supply chain operations, it could unlock the hidden insights in how the supply chain has changed and the knock-on consequences.

6. Future Direction

Based on current trends, we look forward to further evolution in AI and supply chain practices for sustainability. The faster and higher complexity of AI reasoning and data analytical abilities produce greater potential to absorb data from a wide range of IoT sensors in both small and large supply chains. The increased capabilities to sense, predict, and anticipate require real-time adaptive supply chain strategies, matching what is traditionally demanded from service industries and highly perishable products. Additionally, consumers have generated new visions of what is ethical and what is necessary. On a more speculative level, this could manifest in the next 20 years as the importance of life cycle data across the chain and potentially the payment for the right to release products into the supply chain. It is the companies that begin to spearhead the development and deployment of these novel technologies that are more likely to be considered forward-thinking.

One of the most important challenges for supply chain management continues to be the free radicals introduced by greening and consumer-driven sustainability. The challenge has heightened as the mainstream markets now understand the risk that climate poses and have multiple methods to express stakeholder positions to shareholders. Primarily, the future of supply chain management will automatically produce evolution in the AI required to navigate the changes currently underway in sustainability. This includes AI that helps to manage the collateral supply chain benefits such as information security, product recall, transparency, and stakeholder relationships. The networked approach has been hinted at in the foresight of both the Forum of the Future and the UK government as alignment of policies. If true, it will automatically adjust forecasts to ensure global influences bear no lasting negative impact on the business case for sustainability. As with any advance, new hurdles appear. Techniques that support sustainability, such as smart granularity of data to assist small to medium-sized enterprises, have special access and uptake implications. The positioning of the ethics, laws, and regulations of sustainability will ensure continuous development.

7. Conclusion

Many companies are currently facing a wide range of urgent environmental problems: extreme weather events, biodiversity loss, and resource scarcity. Efficient solutions, such as AI in environmental management, are required to ensure that companies can operate sustainably. AI technologies have a significant potential to make supply chains and other relevant activities more efficient and effective. In view of the scarce research that can be found on this topic, there is no doubt that they have the potential to contribute to pressing environmental and ecological problems in the short and long term by allowing organizations to take action to mitigate threats to local and global biodiversity.

We have introduced various types of relevant technologies, such as blockchain, drones, and additive manufacturing, which are already being integrated into supply chain activities and draw attention to their potential to change or disrupt supply chain management. The development of AI still focuses on smart production, but the development in other areas is increasing. AI is about to improve performance across supply chains and can result in cost savings. There are already a number of promising AI applications in logistics, which can also help improve performance. In conclusion, be aware that although AI has been proven to improve performance, it can also damage it if not managed effectively. As such, it is recommended that the process of adopting and implementing new technology should not be carried out haphazardly. It takes time to consider whether it is better to change course or not. Both types of investment take time, require effort and have associated risks. Given that it is apparent that AI is much more than a technological factor, one needs to investigate the potential of AI to do different things or conduct further studies to explore its possibilities in order to come up with more effective courses of action.