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Sustainable Adaptive Supply Chains: Artificial Intelligence as a Higher-Order Capability for Systemic Resilience and Environmental Integration

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Abstract
In this article, it is suggested that there is a new artificial intelligence leaning supply chain which is known to reduce operational costs, support instantaneous supply chain adaptation and supply chain resilience, and uphold the environment, i.e., the concept of Sustainable Adaptive Supply Chains (SASC). In this sense, we argue that AI constitutes a strategic frontier for realizing supply chain process efficiencies, as it enables much shorter recovery times through excitation factors, adaptive transience, and green recovery. Drawing on the tenets of Dynamic Capabilities Theory and recognizing the importance of AI in enhancing the value of underperforming operations, the paper proposes that AI capabilities are fundamental digital infrastructures that enhance sensing, seizing, and reconfiguring activities. The integrated AI-enabled activities will enhance the "spirit" or lack of it within an organization, centered on the required openness to change, which in turn is the core of bootstrapped change (nurture-as-victim nurture concept). Finally, this part discusses both the application of the SASC approach and its limitations, as well as ways to enhance the ability of organizations and territories to improve sustainability.
Keywords: Artificial intelligence; Sustainable supply chains; Dynamic capabilities; Resilience; Sustainability transitions

1. Introduction

There are fundamental changes taking shape in global supply chains, responding to two stimuli that complement each other. These forces consist of an increasing inability to act due to the environment and a sharp increase in factors that undermine the system's stability. Supply chain management has to cope with global warming, greenhouse gas regulations, corporate and social responsibility, etc., driving corporations to minimize emissions, eliminate waste, and realign resources. However, conflicts between global economies, including terrorist threats, military operations, market uncertainties, as well as morbidity, floods, and bubble bursts, have exposed some weaknesses in the supply chains and production and transport. Therefore, enhanced cooperation between the government and supply chains is required in order to consider ecological requirements rather than profitability alone.In the past, the design of supply chains was chiefly influenced by efficiency, flowing from a plethora of lean management ideas. The efficiency logic did work, and it eradicated cost discrepancies and promoted correct process functioning in the physical supply chain, but one of the drawbacks of it was that it reduced duplication and intensified the systemic brittleness. The intellectual wave that came next relating the authors to resilience proposed the ideas of 'flexible forces', 'more of everything', 'type of forces', and 'hazard pyramid'. While this principle of preparing the system against a hazard may be more resilient, it is hardly an efficient way of doing things. Furthermore, the academic field of sustainable supply chain began to address environmental issues, particularly issues related to carbon footprint intensity, energy consumption, and resource conservation; however, these are not mutually exclusive goals of the supply chain were just additional criteria used for monitoring purposes rather than guiding principles in decision-making.

The emergence of supply chain management as a crucial operational and strategic aspect in enhancing the performance of any organization has rendered Artificial Intelligence more of a key in the execution of some crucial functions in society today. Many processes, such as digital twins, predictive analytics, and even some optimization systems, have lessons in control theory within them, but are implemented as control systems. In the business model, these technologies include the systems or operations where neither profit nor loss is incurred, such as marketing. On the contrary, even in the use of these systems, the tertiary sector is not considered outside the scope of management.

Current understanding of this subject is extensive in nature, showing how it acknowledges the need to detect impending threats, quickly formulate alternative or contingency plans, and adjust the structure of the system when the environment is uncertain. Against this background, works on socially responsible business actions are aimed at improving environmental efficiency. However, being connected by a focus on CSR innovation, the above two research areas have both conceptual and empirical disconnections. To the user, these are additionally some of limiting factors in the respective inclusion and elaboration of aspects of AI-driven decision support aimed at reaching Environmental objectives in agile enterprise systems without compromising its productivity w.r.t capacity and adaptability.This research aims to fill that void by defining the Sustainable Adaptive Supply Chains, known as SASC. The Sustainable Adaptive Supply Chain concept refers to both an enhanced organisational capability and a new supply chain configuration shaped by emerging AI-enabled real-time shipment coordination. To put it simply, there is no expectation of what is typically referred to as sustainability as a regulatory compliance. Likewise, financial proportions do not have to be just minimised through duplication of processes/supplies as an effective risk management strategy. Rather, adaptive strategic decisions, environmental constraints and probabilistic uncertainty are encoded within details under the operating decisions and tools through the service of sensing, seizing and reconfiguring capabilities based on artificial intelligence.In the context of the resource-based view and dynamic capabilities the author proposes to consider artificial intelligence capabilities as enabling digital infrastructures, which are building industries capabilities with adaptable mechanisms that will normalize SASC. The research will then explore and create scenarios that demonstrate the work of these mechanisms in the so-called avant-garde supply chain firms. The model advances the concept that SASC transforms the old dilemma of balancing efficiency against resilience in trade-offs with the achievement of environmental objectives into geared optimality with a great emphasis on information use.This work has several implications. In the first place, SACS is developed as a synthesis which brings together differing viewpoints in the literature in AI, resilience, and sustainable supply chains. Furthermore, leverage from the Dynamic Capabilities Theory is given in that AI is investigated as a catalyst in achieving sustainability in any organization. On the ground, NR is deployed by building Environmental Performance and eco-efficiency values into algorithms and the multiple DEC systems employed. Finally, it adopts a maturity approach in the development of policies and strategic plans for the organization, transforming AI from being a usually implemented in isolation to being a system that is designed to encourage and sustain behavior that is in line with the principle of sustainability.In this study, SACS is recognized as both an upper ADTech and the underpinning DESIGNTech having emerged from AI enabled adaptive coordination, highlighting the integral and fundamental roles of intelligent technologies in changing supply chain processes in the pursuit of sustainability.

2. Literature Review

2.1 Artificial Intelligence in Supply Chain Management: Supply chain management is undergoing digital reforms, and in particular, the use of artificial intelligence (AI) is being used as an integral part of that transformation. The past couple of years has seen great improvements in terms of applications of the state-of-the-art technologies including machine learning, predictive analytics, optimization algorithms, digital twins, which have really revolutionized forecasting – inventory positioning – logistics. (Dubey et al., 2021; Ivanov & Dolgui, 2020; Wamba et al., 2021). Backing up a prediction performance or an efficiency of inventory management algorithms predicated on mathematical models even more, those techniques can also make a mark for themselves and refer to AI technologies. In these contexts, machine learning or AI powered forecasting systems along with fully or partially autonomous optimization systems do not just decrease uncertainty but mitigate bullwhip disturbances too. The business even has better resources, servers, and distribution routes to deliver products on time without any disturbances (Obwegeser et al., 2022; Im and Ochkov, 2022). The majority of scientific and expert works typically emphasize AI, like the technology that enhances the level of the operations of an organization continuously such as performance. Because processes and benefits can very easily be measured empirically, people often take AI as a form of precision, cost reduction, faster lead time and better service improvement (Bag et al., 2023). Instead of acknowledging the basically critical impact and functions and its potentialities in terms of reshaping the industry, these studies are quite limited in as much as they emphasize the integration of AI as something supplementary to the extant supply chain structures.

New research has recently started exploring how AI can better enhance network discovery and synchronization through virtual twins or real-time analytics devices (Ivanov, 2021; Queiroz, et al., 2022). These advancements allow for the calculation of containment benefits related to disruptive circumstances and improve decision-making in uncertain contexts. Nevertheless, concerns on environment are often seen as a residual positive effect or compliance indicator and not as a decision requirement. Without such 'plug-in' of sustainability strategies, AI cannot be called sustainable adaptive supply chain (SASC).

2.2 Supply Chain Resilience and Adaptive Capacity: Supply chain resilience research has responded rapidly due to rapid worldwide shocks, including pandemics, geopolitical conflicts, and environmental effects (Chowdhury et al., 2021; Wieland & Durach, 2021). Resilience has usually been defined as the capacity to withstand, absorb, adapt to, and, if necessary, recover from a wide range of disasters or hazards (Christopher et al., 2006; Tukamuhabwa et al., 2015). Existing resilience strategies often focused on practices that dealt with redundancy, such as safety stock, multiple sourcing, and geographic expansion. However, these approaches, although effective towards managing risks, are mostly associated with setting a higher level of operational costs and are incompatible with lean operations (Ponomarov & Holcomb, 2009). This contradiction perpetuated a common trade-off narrative with respect to the efficiency and resilience implications of the design of the supply chain (Brandon-Jones et al., 2014). In his recent article on risk and resilience in supply chain management, Ivanov said that contemporary scholarship argues for a shift in the focus on resilience as a strategy to mitigate risks associated with volatility in supply chains. Instead, they propose that resilience management should be sought as a way of designing and managing responsive and adaptable supply chain designs, which they term adaptation design and progression. Furthermore, scholars propose that stronger resilience, which is cost efficient in order to avoid overinsurance or excess stored stock, may be more effectively about size of capacity and resource holding capacity of organization that comprises either multiple supplies or multiple supplies by same vendor provides such resilience capability.

2.3 Sustainable and Green Supply Chain Management: In the ongoing researches of sustainable supply chain management, focuses have mainly incorporated attachment of environmental and social elements to the procurement practices, the production processes, distribution strategies, and reverse logistics methods (Carter & Rogers, 2008; Seuring & Müller, 2008). Hence, the right approach will be to pursue strategies that focus on reducing carbon emissions, using energy more effectively, changing the behavior in the use of resources through ideas such as closed-loop systems, and even analyzing the product and its effect on the environment (Genovese et al., 2017).

The Natural Resource-Based View of the firm argues that environmental capabilities may be next sources of competitive advantage, if they are institutionalized and performed by the firm (Paladino, 2007). The main attention to the inherent advantage of developing eco-friendly procurement procedures lies with the fact that sustainable business models do not create a disparity between economic growth and environmental degradation (Zurki & Suchopelsky, 2002).Even though certain advancements in the field have recorded positive milestone, sustainability preventions have remained fear driven institutions or such that have only been implemented in them due to external demands like those from accounting forums where economic based activities are discussed. Such wasted efforts and resources ought to be directed in sustaining an organization structure of hospitals (Busse et al., 2017). Prospects like blockchain, the Internet of Things (IoT) and predictive analytics have been identified as enablers of sustainability (Elenbourgh et al., 2016), though a cogent system that bridges self-adjusting capabilities of artificial intelligence with the Green Balance concept is not as well developed. It is relevant that environmental performance can only be said to become structural as far as sustainability measures would be considered part of self-adjusting decision architectures in accordance with the SASC framework.

2.4 Digital Transformation and Dynamic Capabilities: Dynamic Capability Theory focuses on how organizations react under changing circumstances and in the face of environment changes interestingly (Teece, 2007). Sensing changes in the market situation, creating ions and crystals by seeking these changes, puzzling, and reengineering assets to sustain competitive advantage are the key focal points in the framework. In the same vein, scholars have leveraged the literature on dynamic capabilities to the sphere of information technology in terms of virtual integration as well as organizational design, and knowledge management, in emphasizing the significance of the concept of big data analytics and AI (Mikalef et al., 2021; Warner & Wäger, 2019). These digital means are capable of carrying out changes in the company's business environment and managing operations flexibly ignoring organizational structure.

Nevertheless, in many cases, research conciders digital transformation and sustainability as two distinctive phenomena. Very few research papers have taken an initiative to research on new AI-based paradigms by which orgainzations can enable embedding environmental performance within adaptive supply chain mechanisms. The need for an approach that integrates digital intelligence, resilience, and sustainability while still maintaining theoretical unity is also evident, thus bringing resources back to my paper (tertiary integrity).

2.5 Reconsidering the Trade-Off Logic: There is a misconception in supply chain literature that efficiency, resiliency and sustainability are at odds with each other. On one hand, leanness prioritizes cost saving and reduction of inefficiencies but could insufficiently respond to changes in the system. Resilient system would involve building layers of additional resources which tednds to increase overall cost of operations. In this final case, the addition of temporary assets for sustainable sourcing may require initial capital, which scales down the activities and profits of the company (Pagell & Shevchenko, 2014).Recent advances in information processing involving AI, however, throws or questions this venerable belief. Indeed and applying technology, AI may, with enhanced visibility, reduce risks and allow for more accurate Enterprise Inventory Optimization (EIO) and Demand-Driven Replenishment (DRO) (Lukman, Agserv). It has been argued that optimization algorithms have the capability to reduce fuel consumption and transportation costs at the same time which suggests a shift away from environmental and economic aim divergence (Bag et al., 2023). Different researchers have presented these phenomena from various perspectives. However, the holistic logic of how the AI abilities disturb the equilibrium among effectiveness, stability and the sufficiency – which I would rather idealize

– has not yet found its way in the written form. On the other hand, the trade– off attitude has been going on throughout the entire article due to the fact that the comprehensive perspectives are not fully developed.

2.6 Toward Sustainable Adaptive Supply Chains: The exploration of adoption of AI and development of resilience theory, sustainability studies, in addition to digital dynamic capabilities and their components reveals a considerable absence of research. Current research does not aim at a universal understanding of how the environmental aspect can be structurally integrated in the procurement environment in light of AI. A new thesis is put forward in this paper the Sustainable Adaptive Supply Chains (SASC) to bridge this gulf. This new thesis belongs to the family of dynamic capabilities since it builds on the notions of dynamic capabilities as proposed by Teece (2007) and the Natural Resource-Based View **(**NRBV) of Hart (1995), and understands decision intelligence as the extent of ARI to the extent that it engages environmental constraints within the space of adaptive sensing seizing and reconfiguration processes.

In this context, environmental dimension is more of a specific objective rather than an aspect coming after the assessment of performance, meaning in processes of optimization. In this case, resilience differs from the quantitative view of static redundancies it corresponds rather to the qualitative aspect of changes that provides for more natural and ecological construction and conservation on one hand and on the other hand to rationalized work that avoids unnecessary restorations. Articulating SASC, in both, a higher-order capability and a supply chain design logic, implies that digital transformation is a move which will aid to achieve a systematic environmental change.

3. Conceptual Framework Development

3.1 Sustainable Adaptive Supply Chains as a Higher-Order Capability: This paper argues that Sustainable Adaptive Supply Chains (SASC) can be seen as an organization-wide structure that incorporates operational effectiveness, innovation, and greenness in a superior approach to decision-making. In contrast to traditional supply chain forms which view the three of them as mutually exclusive, within SASC, the issue is a combined one where adaptive coordination policies aim at bringing about positive impacts both in making financial gains and solving environmental challenges. SASC, being a higher level graspable construct, embodies dependent first order pointers presenting as sensing, reacting, and resettling respectively in procession to thermal mechanical equilibrium. This may promote the availability of these boundaries within the supply chains through its stress-testing principles motored by the reinforcement learning and the logic rules. The observed included environmental protective activities include balance in maintenance of operational efficiency, resistant strategy formation and environmental sustainability that research it as opposed to isolated results.Therefore, SASC is not just a recognized entity but also described as a setting that complements capacities taking the form of a supply of the utmost extent. It precludes the optimization, and more important, it requires a return to a leaner and flexible approach which can be related to supply constraints and vulnerabilities which are building and designing the supply chain.

3.2 Artificial Intelligence as Enabling Infrastructure

Artificial intelligence provides the foundational digital infrastructure enabling SASC's emergence. Four core AI capability domains are central:

1. **Predictive Analytics Capability** – Machine learning models for demand sensing, risk prediction, and emissions monitoring.
2. **Optimization Capability** – Algorithmic decision engines integrating cost, service, and environmental variables.
3. **Digital Twin and Simulation Capability** – Real-time virtual replication of supply networks enabling structural scenario testing.
4. **Autonomous Execution and Visibility Capability** – End-to-end platforms supporting real-time coordination and automated adaptive response.

These capabilities expand organizational information-processing capacity, reduce uncertainty, and enhance decision precision. However, AI does not directly produce sustainability or resilience outcomes. Instead, AI strengthens dynamic capability mechanisms that collectively institutionalize SASC.

3.3 Mechanisms of SASC Emergence

There are three interrelated mechanisms that are based on the Dynamic Capabilities Theory which can be used to explain the relation between AI capabilities and SASC emergence:

Enhanced Sensing: Predictive systems integrating such tools assist in detection of variation in demand, characteristics of disruption, and major factors connected with environmental performance. In addition, object requirements stipulated within shorter timeframes are centralized; that provides easy access to information about any local hot resources or inefficiencies, emissions included.

Adaptive Seizing: People who work in the field of optimization embrace the challenges of resolving the conflicting interests of economic and environmental protection components. In this framework, adaptive behavioral optimization is a valiant advancement and introduction of operational emissions, environmental efficiencies and biodegradable utilization together with routing features among others.

Structural Reconfiguration: Digital twin technologies, as well as simulation systems for forecasting outcomes, make it possible to reorganize in-house activities in sourcing, transportation, storage, geographical allocation and capacity in order to change covering changes in the environment and disturbances. This also solves the problem of separate sustainability policy by translating such policies into the logic of network configuration rather than pre-coordinating it with the fixed infrastructure pace.

With these articulation strategies deployed in repeated action, the use of AI enhanced adaptive processes advances from being an ability to developing an approach at the organizational level.

3.4 Propositions

The following six propositions articulate the mechanisms underlying SASC formation:

1. Proposition : AI-enabled predictive analytics strengthens sensing mechanisms, contributing to the emergence of SASC.

2. Proposition. AI-driven optimization capabilities enhance adaptive seizing processes by integrating economic and environmental decision variables, reinforcing SASC formation.

3. Proposition : Digital twin and simulation capabilities improve the effectiveness of structural reconfiguration, accelerating the institutionalization of SASC.

4. Proposition : Adaptive reconfiguration mechanisms within SASC mediate the relationship between AI capabilities and environmental sustainability performance.

5. Proposition : SASC reduces traditional trade-offs among operational efficiency, resilience, and environmental sustainability by enhancing uncertainty reduction and coordinating optimization.

6. Proposition : The intrinsic advancement of AI-based dynamic capabilities within the organization is useful in producing a strong and impermanent balanced SASC structure.

When these assumptions are taken collectively, they point out SASC as the all-uniting structure that bridges AI-based dynamic mechanisms with reinforcing performance effects.

3.5 Boundary Conditions

The development of SASC is contingent upon several contextual factors:

1. **Data Integration Maturity** – Effective sensing requires high-quality, interoperable data systems.
2. **Governance Alignment** – Sustainability objectives must be embedded within strategic and operational governance structures.
3. **Regulatory and Institutional Pressure** – Environmental transparency requirements influence the embedding of ecological constraints.

4. **Organizational Coordination Capability** – Cross-functional integration supports adaptive implementation.

In contexts characterized by limited digital infrastructure or weak sustainability governance, AI deployment may improve operational efficiency without fully institutionalizing SASC.

3.6 Comparative Positioning of Supply Chain Paradigms

To clarify conceptual boundaries, Table 1 differentiates SASC from related supply chain paradigms.

Table 1: Comparative Positioning of Supply Chain Paradigms

Dimension	Digital Supply Chains	Green/Sustainable Supply Chains	Resilient Supply Chains	Sustainable Adaptive Supply Chains (SASC)
Primary Focus	Automation and data integration	Environmental impact reduction	Disruption recovery	Integrated adaptive coordination
Role of Technology	Operational efficiency tool	Support for environmental initiatives	Risk detection and response	Foundational infrastructure for adaptive sustainability
Sustainability Integration	Often indirect	Central but sometimes compliance-driven	Limited	Embedded within optimization and reconfiguration
Resilience Mechanism	Improved visibility	Not the primary focus	Redundancy and flexibility	AI-enabled sensing and structural adaptation
Trade-Off Framing	Efficiency dominant	Sustainability–cost tension	Efficiency–resilience tension	Trade-offs reframed as adaptive co-optimization
Theoretical Anchor	Digital transformation	NRBV	Resilience theory	Dynamic Capabilities + NRBV integration
System Orientation	Process-level	Environmental objective level	Risk management level	Network-level adaptive systems paradigm

This comparison serves to highlight that SASC is not just a new name for projects transformation, focusing on green or digital supply chains. In contrast, it is a reworking that includes artificial intelligence orchestrated adaptive systems fortunately compatible with the goals of eco-friendly designs and logistics practices.

4. Structured Case-Based Validation

4.1 Method of Case Synthesis

To reduce anecdotal in nature bias and keep the analytical issue under focus, the paper takes an approach of a structured case synthesis. The intention is not a qualitative case research but a practical example of the embodiment of the various Sustainable Adaptive Supply Chains (SASC) controls.

Case selection followed three criteria:

1. Applied AI integration in supply chain operations. Some examples of such technologies are predictive analytics, optimization systems, digital twins, or autonomous execution platforms.
2. A transparent and stated sustainability strategy that covers environmentally friendly operational procedures and performance targets.
3. The essence of the international supply chains and networks is that they control vulnerability against internal and external risk, and manage challenges to their adaptability in the dynamics of the global economy.

Kranz (2016) has four identified global institutions subject to these qualifications, including Amazon, DHL, Alibaba Cainiao, and Maersk. Until now, there has not been a single study that examines the application of AI in the management of supply chains in the selected organizations. Nor has there been a single study that examines the effect of AI utilization of supply chains to various extents on the condition of its fulfillment.

4.2 Case Illustrations

4.2.1 Amazon: Amazon utilizes artificial intelligence in the form of predicting future parameters, Trending information introduces fresh perspectives, up to and even in the redistribution of stock. Algorithmic approach also exists, leveraging machine learning algorithms again, oriented toward synchronization of production/distribution.

Algorithms: The Essential Systematic Solutions to Frictions in the Market

This phenomenon illustrates how the use of artificial intelligent sensing, seizing, and reconfiguration processes inspire the imposition of SASC.

4.2.2 DHL: AI-driven route optimization technologies and emissions monitors that were tailored to the specifics of DHL's logistics activities, were a part of these measures. With the field of algorithms for environmental management optimization, they worked efficiently in commercial services whereas maximizing efficiency of delivery effectiveness. Presents of environmental emissions data have been useful on the front of transportation optimization, since the top emissions user's account of variation in the transport chain.

4.2.3 Alibaba Cainiao: Alibaba's Cainiao logistics network utilizes Real-Time Chunking (RTC), AI-powered Digital Freight Forwarders (DFFs), and JDs in its cross-border operations. Putting these last two concepts into practical use by adapting homeland theory to cross-border theories can help solve these types of problems. A change to the entire system enables the elimination of suboptimal functioning, reduces resource waste, and improves the system's effectiveness at similar capacity levels.

The Alibaba Cainiao case is a good example to show that AI-enabled adaptive coordination strengthens the idea of SASC in supply chain operations

4.2.4 Maersk: Computerized angling engines and AI-based management of such are used for Maersk Line in order to cut fuel costs and optimize the order of ships for particular journeys. Adaptive shipping, due to emergent contingencies, is able to address environmental concerns in the decision-making process of maritime logistics. "The focal point of this part of the negotiation involves how the sustainability functions were integrated into the company."

5. Pathway Toward Sustainable Adaptive Supply Chains

With a deepening of digital competence and convergence with modes of functioning, the formation of SASC spirals along a path that subsequently consolidates into three basic stages.

Stage 1 – Pre-SASC (Efficiency-Oriented AI): AI is commonly used by some organizations for two main reasons: to improve cost efficiency and to ensure that the service quality offered is dependable. Any societal improvement is seen more as an unintended consequence of AI implementation rather than as a built-in feature. The extent to which AI may be deployed within an organization is inclined towards the optimizing its operations.

Stage 2 – Transitional Adaptive Supply Chains: Future experiments aim to become more specialized so that researcher can better invest their study time. Although the exact emphasis of environmental benefits or sustainability is not fully incorporated into projects due to the lack of available options.

Stage 3 – Mature SASC: AI-driven adaptive control is well integrated into the performance considerations of operational constraints. Algorithmic latency supports the viability of the multidimensional reverse logistics model. This is because efficiency, resiliency, and environmental outcomes become operationalised in the same deployment.

Table 2

SASC Maturity Model

Stage	AI Focus	Adaptive Capability	Sustainability Integration
Stage 1	Operational optimization	Limited sensing	Indirect/Incidental
Stage 2	Risk visibility and simulation	Adaptive reconfiguration	Emerging integration
Stage 3	Carbon-aware optimization	Institutionalized dynamic coordination	Fully embedded

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6. Theoretical Contributions

The current research has a few meaningful implications for the field. Firstly, it extends SASC as an integrating construct that converges the dichotomies posed by AI, resilience, and sustainable Supply chain. Secondly, it develops the ideas of Capabilities Theory by uncovering the mechanisms by which AI valorizes sustainable transitions at the ecosystem level and at the market scale. Thirdly, it presents the R-premature and the Natural Resource-Based View (NRBV) model, addressing bio constraints through the application of auto algorithms. And fourthly, it reconsiders how provisioning of efficiency, resilience, and sustainability functions can be put into competitive policies in the new era characterized by Information and Communication Technologies (ICTs).

7. Discussion: Systems and Sustainability Transitions

SASC is conceived as a transformational change in supply chain governance that appreciates the system as a whole. Instead of the paradox of finding a sub-optimisation in processes, SASC leverages digital power in the face of environmental and resilience consciousness at the network level. By integrating carbon intensity and state-depleting resources into decision-making, SASC successfully implements such sustainability transitions at the organizational level.

The framework's goals align with the United Nations' SDGs, most importantly by tracking sustainable development. The 9th SDG addresses attaining broader economic goals within industry and infrastructure; the 12th focuses on sustainable production and consumption policies; while the 13th concentrates on the issue of man-made climatic abnormalities. Using the principle of adaptation and coping strategies, SASC will restrict freight and labour within supply chain models.

In developed systems using SASC, digital options may effectively reduce such traditional trade-offs, but there is a risk of unintended rebounds and clashes with prevailing ideologies, which can compromise the green benefits if society's metrics are not well integrated.

We suggest that SASC is a second-order construct; some maturation in other industries should be examined, and the effect of regulatory incentives on the embedding of environmental aspects in construction processes facilitated by AI should be investigated.

8. Conclusion

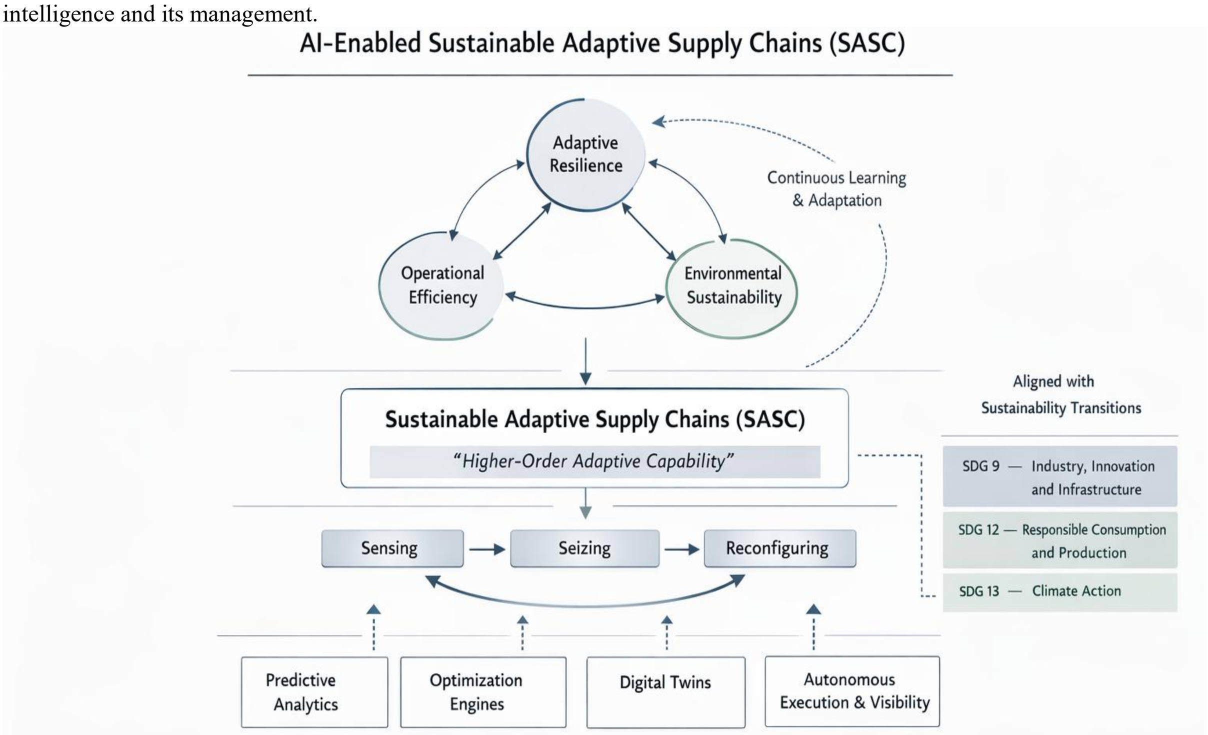
By viewing Sustainable Adaptive Supply Chains as a strategic capability and an architecture for managing supply chains, this research advances the conversation beyond digital efficiency to structural sustainability. In this sense, AI technology is not simply used to optimize static problems within the supply chain network; rather, it becomes a platform that embeds adaptability and environmental consciousness. SASC represents the progression of how supply chain management is viewed, moving from a focus on supply chain management to a vision of sustainable systems-change intelligence and an integrative approach.

This article spotlights Sustainable Adaptive Supply Chains (SASC), a new supply chain design philosophy enabled by artificial intelligence (AI). In the visual abstract, four stages are depicted, each with AI components that significantly increase adaptive capacity through enhanced sensing, seizing, and reconfiguration. The elevated managerial order of capability named SASC is produced through the operation of the above-mentioned mechanisms.

The concept of SASC involves advancing the three goals of operational productivity, adaptive capacity, and environmental management within the performance system. Instead of looking at operational productivity, adaptability, and environmental management as counterbalance objects, they are considered reinforcing objectives. There is a capability cycle incorporated into the SASC framework, which accounts for constant learning and development. The conceptual framework also encompasses the transformation of businesses digitally, including the environment, by including carbon-aware decision variables directly within adaptive supply chain operations.

Rather than defaulting to the conventional approach that requires people to make difficult choices, the use of the theoretical model re-conceptualizes such dichotomous situations as positive strategic objectives that seek to improve AI in supply chain practices within the larger social–environmental goal framework, including broader targets.

In the framework of such concepts as AI and sustainable development, for example, AI-enabled Sustainable Adaptive Supply Chain (SASC), resource-saving systems, information systems, or even individual technological devices can be considered as the various levels of artificial intelligence and its management.



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