Path Analysis of Supply Chain Management Reform Driven by Data Empowerment

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Abstract: Amid converging digitalization and sustainability imperatives, this study advances a conceptual framework integrating artificial intelligence (AI)-enabled analytics, supply chain centralization, and green supply chain management (GSCM) as mutually reinforcing drivers of supply chain performance. The framework posits that when synergistically combined with AI and environmental imperatives, centralized governance structures generate superior efficiency-sustainability outcomes. Empirical validation was provided through a comparative case analysis of Unilever and Hailan Home (HLA), illustrating divergent integration pathways. Unilever's globally centralized, data-driven, and sustainability-aligned supply chain strategy contrasts HLA's efficiency-focused model. Results demonstrate that triadic integration facilitates enhanced visibility, operational agility, and environmental performance. The findings contribute to SCM theory by aligning resource-based and dynamic capabilities perspectives with environmental strategy while offering actionable managerial insights on orchestrating digital, structural, and green initiatives. The study concludes that strategic alignment across technological, organizational, and ecological dimensions is foundational for competitive resilience in data-driven supply ecosystems.

1 INTRODUCTION

Global supply chains today face dual pressures to improve operational efficiency while meeting sustainability targets amid rapid digitalization (De et al., 2016). Firms must cut costs and boost speed to stay competitive even as stakeholders demand greater environmental and social responsibility throughout the supply chain (De et al., 2016). These twin imperatives have fueled interest in data-driven supply chain management-leveraging big data analytics and AI for decision-making—and green supply chain management (GSCM) that integrates sustainability into SCM practices. At the same time, companies are reconsidering structural strategies; for example, many are pursuing supply chain centralization to gain better control and economies of scale in a volatile global market. This study is motivated by the need to understand how these three themes-AI-driven decision-making, centralization, and GSCM-can be integrated to achieve a "double win" of high performance and sustainability.

This research addresses the following questions. First, how can a centralized, AI-empowered supply chain enhance operational efficiency and environmental sustainability. Secondly, does increasing supply chain centralization lower costs and improve performance, and under what conditions. Third, how do GSCM practices impact firm performance-can companies "go green" and still improve profitability. Finally, are AI-based supply chain analytics (e.g., demand forecasting and inventory management) superior to traditional methods, and how do they influence outcomes like service levels and waste reduction. By examining these questions together, the study addresses a gap in prior research – most studies have considered these strategies in isolation, whereas their interaction may unlock additional performance gains (Nguyen et al., 2022).

The contributions are twofold. Theoretically, this work develops an integrative framework linking SCM strategy (centralization vs. decentralization), technological innovation (AI and data analytics), and

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sustainability (GSCM), extending supply chain management theory to encompass their interplay. Practically, it analyses two industry cases-Unilever (fast-moving consumer goods) and HLA (apparel retail)-to illustrate how organizations can implement these strategies in tandem. The findings offer actionable insights into managers redesigning supply chains to be more data-driven and green while maintaining cost-effectiveness. In sum, efficiency and sustainability need not be a trade-off; with the strategic integration of AI, structural centralization, and green practices, firms can achieve synergistic improvements in supply chain performance.

2 LITERATURE REVIEW

In contemporary supply chain scholarships, artificial intelligence (AI), supply chain centralization, and green supply chain management (GSCM) are prominent, interrelated paradigms for enhancing performance. AI-driven analytics has improved demand forecasting, inventory management, and responsiveness (Arunachalam et al., 2018; Dubey et al., 2019). Mäenpää (2024) contends that AI has become essential for harnessing big data and embedding predictive intelligence into supply chain decision-making. Concurrently, centralizing supply chain control yields coordination benefits through risk pooling and economies of scale, as formally quantified by Eppen (1979) in classical inventory theory and demonstrated in practice by Brito (2016). However, excessive centralization can diminish local agility; thus, scholars advocate balancing central authority with decentralized flexibility (Qi et al., 2017).

GSCM extends traditional SCM by integrating environmental sustainability across all supply chain activities (Srivastava, 2007). A robust body of literature finds that GSCM practices often jointly enhance environmental and operational performance, challenging the notion of an efficiency–sustainability trade-off (Zhu & Sarkis, 2004; Kalyar et al., 2019). For example, companies adopting eco-efficient processes have realized cost savings and revenue gains from green products (Feng et al., 2017). Researchers also note implementation challenges, including higher upfront costs and supplier coordination complexities (Mudgal et al., 2010; Walker et al., 2008). Although some have posited the "fallacy of profitable green supply chains"-the idea that sustainability gains may initially come at the expense of profitability (Esfahbodi et al., 2023)-the prevailing view is that well-executed GSCM ultimately bolsters long-term efficiency and resilience (Green et al., 2012; Zhu et al., 2013) while advancing sustainability goals. Moreover, these three paradigms are increasingly regarded as complementary. AI and centralized data systems can amplify GSCM outcomes by optimizing resource use and enabling agile, sustainable decision-making, thereby aligning efficiency with environmental responsibility.

3 INTEGRATIVE THEORETICAL SYNTHESISM

Synthesizing the discussion, a conceptual framework interlinks AI-driven decision-making, supply chain centralization, and green supply chain management (GSCM) as core elements of a data-driven sustainable supply chain strategy. While each component independently influences performance, their integration yields synergistic benefits and mitigates trade-offs that arise in isolation.

A key interplay exists between AI capabilities and a centralized supply chain structure. Centralization entails reduced flexibility, but AI-driven analytics can mitigate this drawback by enabling the centralized system to sense and respond to local variations. In a centralized model, large volumes of data from all regions are funded into a single hub; AI is essential to process this data in real time and provide decision-makers with location-specific insights. An AI-enabled control tower can detect regional demand shifts and adjust plans, accordingly, imbuing a centralized system with adaptability akin to decentralization. Moreover, centralization provides a unified IT infrastructure-a coherent data repository for algorithms-and a clear mandate for innovation, factors that expedite AI deployment. In resource-based view (RBV) terms, combining a centralized structure with AI capabilities creates a complex, hard-to-imitate resource that confers a sustainable competitive advantage (Barney, 1991). A positive interaction is evident: centralization offers the scale and data coherence on which AI thrives, while AI reduces centralization's risks by enabling data-driven agility.

AI enables GSCM, equipping firms with tools to monitor and optimize environmental performance. Firms integrating AI into GSCM can use it for real-time carbon footprint tracking and pinpointing inefficiencies driving emissions. AI-driven optimization models balance cost and ecological objectives, finding sourcing, production, and logistics solutions that might elude human planners. Qu and Kim (2024) observe that current AI applications in

sustainable SCM mainly address environmental and economic goals, while social dimensions lag (Qu & Kim, 2024). This suggests AI is well-suited to pursue cost efficiency and environmental impact reduction jointly—the precise overlap of GSCM targets. In this framework, AI augments GSCM by managing complexity (e.g., life-cycle assessment data) and enabling continuous tracking of green performance metrics. Conversely, GSCM priorities (e.g., reducing carbon or hazardous material use) spur novel AI applications beyond traditional cost and service metrics.

Centralization and GSCM are complementary: a centralized structure facilitates uniform implementation of environmental standards across the organization. A central procurement function can enforce green policies enterprise-wide, whereas decentralized units might lag in compliance. Unilever's centralized European logistics network enabled a concerted push that cut transport CO_2 emissions by 20% over five years (De et al., 2016), aligning logistics operations with corporate sustainability targets. Centralization can, however, also concentrate on environmental impact (e.g., one large warehouse may increase transport distances). However, judicious network design (e.g., regional hubs and optimized routing) can offset this by reducing total miles travel, increasing load efficiency, and lowering emissions per unit.

AI, centralization, and GSCM push the performance frontier to new heights when implemented in tandem. Centralization with AI markedly improves operational metrics (speed, cost, service); centralization with GSCM enhances environmental performance without undermining efficiency; and AI with GSCM ensures that sustainability improvements are achieved cost-effectively. Thus, at the intersection of all three, a firm can attain strong economic performance alongside strong environmental performance-a win–win scenario.

This integrative framework aligns with emerging perspectives in strategic supply chain management and operations research that emphasize multifaceted capabilities. For instance, the notion of a "digital supply chain for sustainability" suggests leveraging digitalization (AI, big data) for sustainability objectives, not just operational goals (Büyüközkan & Göçer, 2018). The framework extends this concept by incorporating a centralization dimension. It also aligns dynamic capabilities theory, which posits that firms must continually adapt structures, technologies, and objectives to sustain performance in changing environments.

Integrating AI, supply chain centralization, and green practices yield a holistic approach that drives superior operational and environmental performance. The following case analyses of Unilever and Hailan Home (HLA) demonstrate how this integrated framework operates in practice, providing empirical insight into its benefits and trade-offs.

4 CASE ANALYSIS

4.1 Unilever: Data-Driven Centralization and Green SCM on a Global Scale

Unilever is among the world's most significant fast-moving consumer goods (FMCG) companies, producing food, home care, and personal care products sold in over 190 countries. By the mid-2000s, Unilever's European supply chain was highly fragmented along national lines, resulting in duplication and suboptimal asset utilization. Around 2008, Unilever launched Ultralogistik, a significant initiative to centralize European logistics via a single control tower and a network of regional distribution hubs. In parallel, Unilever emerged as a corporate sustainability leader, introducing its Sustainable Living Plan in 2010 with ambitious environmental targets (e.g., halving the environmental footprint of its products). By the late 2010s, the company also began substantial investments in digital supply chain capabilities, including predictive analytics for demand forecasting and optimization tools, to further streamline operations.

4.1.1 Centralisation Strategy

Under Ultralogistik, Unilever consolidated transport planning and warehouse management across multiple European countries. Rather than each nation managing logistics, a centralized control tower coordinated shipments across markets. This restructuring yielded classic efficiency gains: service levels improved, and costs declined markedly. Over five years, Unilever's on-time in-full delivery performance increased from ~97.5% to 98.8%, accompanied by a 20% reduction in transportation CO_2 emissions and roughly € 91 million in annual logistics cost savings (De et al., 2016). These improvements were directly attributed to centralized coordination. For example, cross-market truck consolidation minimized empty runs, and risk pooling at central warehouses optimized inventory levels by eliminating inefficiencies hidden in siloed

national operations (De et al., 2016). Centralization also enhanced visibility: a unified system allowed Unilever to track end-to-end performance metrics and identify bottlenecks that decentralized systems had obscured (De et al., 2016). Furthermore, the company was able to standardize best practices across the network. Unilever reported benefits such as greater purchasing leverage and a unified delivery process leading to fewer errors and delays, confirming theoretical expectations that centralization yields economies of scale and consistency (Unilever, 2015b; De et al., 2016).

4.1.2 Data-Driven and AI Initiatives

Having established a centralized data infrastructure, Unilever aggressively incorporated advanced analytics and AI into its supply chain operations. The company developed sophisticated demand forecasting systems utilizing machine learning to factor in promotions, weather patterns, and social media trends. In the ice cream category, where demand is highly weather-dependent-AI-driven models now adjust production and inventory based on temperature forecasts, mitigating overstock during cool periods and preventing stockouts during heat waves. According to company reports, this dynamic, weather-responsive planning helped "cut waste" significantly by ensuring ice creams do not sit unsold in unseasonable conditions. Unilever has also deployed IoT sensors with AI analytics in over 100,000 retail freezers; these freezers transmit real-time stock and performance data to a central platform, where analysis identified opportunities to optimize product placement, yielding a 30% increase in sales in specific markets. This exemplifies how centralizing data collection and applying AI-driven insights can deliver substantial performance gains. Beyond these initiatives, Unilever utilizes AI for supply chain planning and optimization, using algorithms to schedule production and distribution to minimize cost while meeting service targets. Internally, the company reports that AI-driven decision systems have improved forecast accuracy by 15–20% and reduced overall inventory levels by a similar margin without compromising customer service (Unilever, 2022).

4.1.3 GSCM and Sustainability

Sustainability is deeply ingrained in Unilever's supply chain strategy. The company has a comprehensive GSCM program that extends from sustainable sourcing of raw materials (e.g., certified palm oil, tea) to eco-efficient manufacturing (steady reductions in factory energy, water, and waste) to green logistics. By centralizing logistics, Unilever implemented a low-carbon transport initiative, optimizing truckloads and routes with AI tools and substantially reducing transport emissions (De et al., 2016). Additionally, Unilever piloted alternative fuels (e.g., biofuels) and modal shifts from road to rail as part of its centralized planning – efforts that required cross-border coordination, which the central model facilitated. On the distribution side, Unilever's central team pursued packaging reduction and increased the recyclability of shipping materials. The sustainability results of these efforts have been notable. Alongside cost savings, Unilever cut over 15,000 tonnes of CO_2 annually from its European logistics network by consolidating loads and adopting greener transport modes (Brito, 2016). Globally, by 2020, Unilever had eliminated non-hazardous waste to landfill in its manufacturing operations and was sourcing a large share of its electricity from renewables– accomplishments driven by policies executed through centralized oversight. One illustrative outcome is that Unilever's "Sustainable Living" brands (its product lines most fully aligned with sustainability objectives) accounted for 75% of the company's growth in 2018 and grew 69% faster than other brands. While this extends beyond supply chain operations, coupling sustainability with core business strategy can yield competitive advantages. From a supply chain perspective, Unilever successfully integrated GSCM into its centralized, data-driven model – for example, centrally enforcing stringent emissions standards for all logistics partners and tracking compliance via data systems (Smart Freight Centre, 2021).

4.1.4 Performance Outcomes

Unilever's holistic strategy has led to quantitative and qualitative performance improvements. Quantitatively, as noted, service levels (OTIF ~98.8%) and cost efficiency improved post-centralization (De et al., 2016); inventory levels relative to sales declined (inventory turnover increased), and supply chain carbon emissions were substantially reduced. Qualitatively, the supply chain became more agile through data-driven scenario planning and rapid responsiveness to market changes. Moreover, Unilever's reputation and brand equity benefited from its demonstrated leadership in sustainable supply chain practices, engendering goodwill among customers and investors. Overall, Unilever's case indicates that concurrently deploying AI, centralization, and GSCM can create mutually

reinforcing benefits, resulting in a resilient, efficient, and environmentally responsible supply chain-albeit one that requires significant investment and organizational commitment to develop.

4.2 Hailan Home (HLA): Centralized and Tech-Enabled Retail Supply Chain with a Focus on Efficiency

4.2.1 Background

Hailan Home Co., Ltd. (HLA) is one of China's largest menswear retailers, operating a unique model with thousands of stores (primarily franchised or affiliated) nationwide. By the end of 2021, HLA had over 7,300 stores nationwide (approximately 6,579 franchise or affiliate stores and the rest self-operated) (Chen, 2022). China's apparel retail market is intensely competitive and has faced rising labor and material costs and increasingly diverse consumer preferences. HLA attributed its rapid growth and success to relentless cost control and supply chain efficiency in this environment. A core element of HLA's strategy is supplying chain centralization, particularly creating a unified logistics and inventory management system to support its extensive store network.

4.2.2 Centralization Strategy

HLA established a single central distribution park in Jiangsu Province to serve as the primary logistics hub for all stores. Through this hub and a "direct management" approach to franchise stores, HLA maintains centralized ownership of inventory at the headquarters level (a consignment model) and directly manages store replenishment.

This arrangement relieves individual outlets from holding large stocks and pools inventory risk centrally. The central warehouse ships products frequently based on demand, minimizing total inventory while keeping shelves adequately stocked. As a result, HLA has "reduced store inventory pressure" and largely avoided overstocking at individual outlets. Suppose a particular apparel style sells poorly in one region. In that case, the company can swiftly reroute those items to stores where demand is higher rather than marking them down at the original location.

HLA also employs centralized procurement. The firm negotiates with its suppliers (who produce many of its garments) on a consolidated, company-wide basis, securing bulk discounts on materials and manufacturing. This centralized procurement strategy and HLA's significant bargaining power have enabled agreements whereby unsold products can be returned to specific suppliers. In effect, HLA shifts some inventory risk upstream to suppliers through these buy-back arrangements, a practice facilitated by the company's scale and centralized negotiations. This approach further reduces HLA's inventory costs and risk (Chen, 2022).

4.2.3 Technology and AI Utilization

After putting the structural foundations in place, HLA recognized that technology was needed to manage its enormous scale efficiently. In 2014, the company began implementing Radio-Frequency Identification (RFID) technology to tag and track apparel inventory throughout its supply chain. HLA achieved real-time visibility into inventory movements by tagging each item and deploying RFID scanners at its central warehouse and stores. This dramatically improved inventory accuracy and reduced manual stock-taking. According to internal analysis, inventory counting time decreased by roughly 30% after RFID adoption (Chen, 2022).

Building on enhanced data visibility, HLA invested in AI-driven analytics to improve demand forecasting and stock replenishment. It developed AI models to predict fashion trends based on historical sales, seasonality, and in-store customer traffic patterns. It used these predictions to allocate inventory from the central warehouse to stores. This AI-driven forecasting allows HLA to respond swiftly to fast-selling items (triggering rapid restocking) and to detect slow-moving products (prompting promotions or inter-store transfers). HLA's centralized IT system aggregates daily sales data from all stores to feed these algorithms. As a result of these optimizations, HLA reduced its inventory backlog by approximately 30%, with a corresponding decrease in inventory carrying costs. Inventory turnover reached about 4.0 turns per year, compared to roughly 11.5 turns/year for fast-fashion leader Zara. Zara's higher turnover is driven by a highly responsive, semi-decentralized model (shipping new products to stores multiple times per week).

In contrast, HLA's model prioritizes centralized control with slightly longer cycles and strict cost management. HLA's use of AI is still evolving. The company has recently explored AI for design (trend analysis) and dynamic pricing, though those efforts lie beyond our scope here. The key point is that HLA exemplifies a data-enabled, centralized retail supply chain focused on operational efficiency.

4.2.4 Performance Outcomes

HLA's centralized, tech-driven supply chain strategy has delivered significant competitive benefits. The company rapidly rose to become China's top menswear brand by sales, indicating that its supply chain reliably supports thousands of outlets and consistent customer demand. Franchisees benefit from the pooled inventory system through significantly reduced stock risks, which likely facilitated HLA's rapid expansion of franchised stores. The RFID and AI initiatives also improved operational efficiency: annual inventory counts that once took days were completed much faster, and inventory accuracy improved, ensuring high product availability. Inventory record accuracy increased substantially after the RFID rollout (Chen, 2022). Customer service levels remain high because the central system swiftly refills stores as products sell. The trade-off in HLA's model is reduced flexibility: it is less immediately responsive to new fashion trends than Zara's ultra-fast supply chain. HLA relies on robust initial forecasts and mid-season adjustments, so if those forecasts are off, there is a lag before AI-driven corrections take effect. Nonetheless, focusing on cost leadership, HLA's centralized model has successfully driven growth and efficiency. However, unlike Unilever, HLA did not incorporate explicit sustainability initiatives into its supply chain strategy. Thus, it reaped the efficiency gains of centralization and digitalization but did not achieve the environmental improvements that a greener approach could have provided – a gap that may pose a strategic risk as sustainability becomes a more prominent concern.

Both Unilever and HLA illustrate the performance impact of combining centralized supply chain structures with data-driven practices. However, their scope and strategic priorities differ, most notably in their incorporation of sustainability.

5 THEORETICAL AND MANAGERIAL IMPLICATIONS

This research contributes to supply chain management theory by demonstrating that integrating AI-driven analytics, centralized structures, and green practices yields a competitive capability that competitors find difficult to replicate (Kamble & Gunasekaran, 2019). It also shows that digitalization can shift traditional contingency trade-offs: advanced analytics enable a centralized model to remain agile even under conditions such as high-demand volatility that were once thought to require decentralization. Furthermore, the evidence confirms that environmental sustainability can go together with profitability, supporting Porter's hypothesis that eco-efficiency drives innovation and performance. However, institutional context can act as a boundary condition for these benefits: the multinational case firm's intense regulatory and stakeholder pressures led to early adoption of GSCM, whereas the emerging-market firm's weaker external pressures delayed such initiatives. The findings underscore the importance of treating technology, structure, and sustainability as an integrated socio-technical system. Alignment across these domains is crucial since focusing on one dimension in isolation may yield short-term gains but not sustained, long-term performance.

Practically, the results urge managers to pursue an integrated strategy rather than isolated initiatives. Case evidence indicates that investments in AI tools, supply chain centralization, and GSCM deliver the most significant value when implemented together in a mutually reinforcing way. A strong data infrastructure should underpin these efforts since unified data makes AI applications far more effective. Equally important is proactive change management; senior leadership must communicate the benefits of centralization and analytics to overcome resistance. For example, Unilever secured local buy-in by transparently sharing performance improvements and involving local staff in centralized processes (Brito, 2016). Finally, managers should emphasize the natural synergies between efficiency and sustainability to build a compelling business case for green initiatives. Many measures that reduce environmental impact, such as optimizing routes or packaging, also lower costs. Unilever's logistics program, for instance, cut carbon emissions by about 20% while saving approximately €91 million (Brito, 2016), illustrating how integrating AI, centralization, and GSCM can achieve economic and environmental gains (Qu & Kim, 2024).

6 CONCLUSION

This study employed a qualitative, case-based methodology to examine how AI-driven analytics, supply chain centralization, and green supply chain management (GSCM) jointly enhance performance. By comparing two firms-Unilever and HLA-the research finds that an integrated strategy across technological, structural, and environmental dimensions yields synergistic improvements in

operational efficiency and environmental sustainability. Unilever's fully centralized, data-driven, sustainability-focused model achieved concurrent gains in cost, service levels, and carbon footprint, whereas HLA's omission of certain green practices highlighted the missed opportunities when integration is incomplete. These cases underscore that AI and centralization empower agility and precision, while GSCM ensures efficiency gains do not come at the expense of ecological goals.

The findings extend supply chain management theory by bridging strategic, technological, and sustainability perspectives. They support the resource-based view and dynamic capabilities frameworks, showing that unique bundles of capabilities (AI analytics, centralized structures, and sustainability orientation) confer competitive advantages that are hard to replicate.

Practically, this conclusion offers a roadmap for practitioners. It demonstrates that pursuing AI, centralization, and green initiatives in tandem-rather than in isolation-can create complementary benefits. Managers are advised to orchestrate digital innovation, structural alignment, and environmental responsibility holistically, breaking down silos between efficiency and sustainability agendas to achieve long-term resilience.

The insights are drawn from only two case studies, which limits generalizability. It remains challenging to disentangle the individual effect of each component due to their integrated deployment, and the rapid evolution of AI technologies means today's conclusions may require continual revalidation. Future research should, therefore, validate these findings across broader samples and quantitative analyses and explore the underdeveloped social sustainability dimension of AI-enabled centralized supply chains. On this frontier, current AI applications address environmental and economic issues far more than social issues.

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