Achieving Operational Excellence in North American Supply Chains: Assessing the Impact of Digital Transformation and Sustainable Practices

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Abstracts: The North American supply chain, essential to the economies of the United States, Canada, and Mexico, stands as one of the largest trade exporters. However, it has encountered numerous challenges and disruptions since the onset of COVID-19. In response, companies are focusing on enhancing speed and agility within their operations, with supply chain configuration becoming a key priority. Achieving operational excellence in North American supply chains is increasingly linked to the adoption of digital transformation and sustainable practices. There is growing pressure on supply chains across North America to integrate digital technologies and sustainability initiatives to attain operational excellence. This integration includes improving operational excellence methodologies like Lean and Six Sigma, which can be enhanced through digital transformation using technologies such as the Internet of Things (IoT) to boost efficiency. This paper explores operational excellence and the effects of digitalization and sustainability on it. The study employs a mixed-methods approach, incorporating a literature review and a quantitative online survey of 2,000 supply chain professionals across North America, achieving a 78% response rate. By investigating digital innovations and sustainable practices, the study assesses their impact on efficiency, resilience, and stakeholder perceptions. The findings suggest that the adoption of advanced technologies like IoT and sustainable initiatives significantly improves both operational performance and compliance with environmental and social standards.

Keywords: Operational Excellence, Digital Transformation, Sustainable Practices, Supply Chain Management, North America

1. INTRODUCTION

Operational excellence (OpEx) aims to enhance business performance and is closely aligned with the concept of continuous improvement (DeFeo, 2024). It encompasses the systematic application of principles and techniques designed to boost organizational performance while fostering a culture of ongoing enhancement. OpEx represents a mindset that embraces specific concepts and methods to cultivate a culture of excellence, empowering employees at all levels to identify, deliver, and optimize the flow of value to customers (DeFeo, 2024). The frameworks associated with operational excellence focus on quality improvement, efficiency, and waste reduction, making it a prominent topic in the business community. The OpEx framework draws on tools from established continuous improvement methodologies, including lean thinking, Six Sigma, OKAPI, and scientific management. Many organizations initiate operational excellence programs to gain a competitive edge, ensuring that the planning, synchronization, and execution of these initiatives foster sustainability in supply chains by emphasizing efficiency, effectiveness, and cost-effectiveness (Bag *et al*., 2020). However, growing demands from governments and supply chain stakeholders are prompting companies to reassess their operational strategies to include environmental and social sustainability considerations (Mangla *et al*., 2020).

Sustainable supply chains integrate the triple bottom line (3BL) concept, which encompasses ecological, economic, and social dimensions of operations. North America is the world's second-largest market, yet, despite strong regional trade relations and interdependencies, it remains heavily reliant on imports from other countries (Oxford Economics, 2022). This dependence underscores the need to strengthen regional supply chains to achieve operational excellence within businesses and industries across the region. Organizations require a model to guide the sustainability of their operational excellence initiatives (Birshan *et al*., 2022). The mixed results of operational excellence programs highlight the importance of investigating their success, particularly in the context of implementing sustainable operational excellence initiatives (Sony, 2019). In North America, organizations are increasingly relying on two transformative factors—digital transformation and sustainable practices—to meet the complex demands placed on supply chains. These elements enhance productivity while bolstering resilience in the face of supply chain disruptions, such as those caused by the COVID-19 pandemic and climate-related challenges (Doheny *et al*., 2022).

This paper investigates how digital transformation and sustainable practices work together to achieve operational excellence in North American supply chains, with a focus on the role of emerging technologies in enhancing efficiency and sustainability in a post-pandemic, climate-sensitive world.

METHODOLOGY

This paper focuses on achieving operational excellence in North American supply chains and aims to assess the impact of digital transformation on their sustainability. The study employs a mixed-methods approach to explore how digital transformation and sustainability influence operational excellence in these supply chains. The methodology consists of two phases: a literature review and a quantitative survey. In the first phase, a comprehensive search of relevant databases was conducted, using keywords such as “operational excellence,” “operational excellence in North American supply chains,” “achieving operational excellence,” “impact of digital transformation on supply chains,” and “digitalization of supply chains.” This phase narrowed the literature review to English-language papers, journals, articles, and books published between 1999 and 2024 to better understand the topic and its evolution over time. Key databases utilized in the study include ScienceDirect, Springer, McKinsey, Taylor and Francis, and the National Center for Biotechnology Information. Additionally, grey literature from reputable publishers that provided valuable insights into the topic was identified through Google Scholar.

During the screening process, the literature review specifically sought articles addressing operational excellence in North American supply chains while evaluating the effects of digital transformation and sustainability. Inclusion criteria were established, focusing on articles published in English from 1999 to 2024 that addressed operational excellence, its methodologies and applications, North American supply chains, and the sustainability and digitalization of supply chains. Some articles were also retrieved from the reference lists of selected studies. Articles were excluded if they did not concentrate on operational excellence, sustainability, or digital transformation in North American supply chains. Additionally, those deemed to provide superficial knowledge or poor information were omitted, as were articles not in English or published before 1999.

Quantitative Survey

- **Sample Size**: A survey was distributed to a random sample of 2,000 supply chain professionals across North America, achieving a 78% response rate (1,560 valid responses).

- **Questionnaire Design**: The survey focused on the impact of digital tools (IoT, AI, Blockchain) and sustainable practices (emissions reduction, resource optimization) on supply chain performance. Questions were structured using Likert scales (1–5), and multiple-choice questions.

- **Questionnaire Dissemination**: The survey was administered online using SurveyMonkey, with follow-up emails sent to ensure a higher response rate. Industry associations and professional networks also facilitated distribution.

- **Data Analysis**: Data from the survey were analysed using IBM SPSS for descriptive statistics, correlation analysis, and ANOVA to assess the relationships between digital transformation, sustainability practices, and operational excellence.

Participants were informed about the purpose of the study, and consent was obtained before completing the survey. Respondents were assured that their participation was voluntary, and they could withdraw at any time without consequence. The data collected were anonymized to protect participants’ identities, ensuring that no personally identifiable information was shared or exposed in the analysis or reporting. Data were securely stored in compliance with data protection regulations, including General Data Protection Regulation (GDPR) for international respondents. Only the research team had access to the raw data.

RESULTS AND DISCUSSIONS

Operational Excellence

Operational excellence refers to an organization’s strategy for delivering unparalleled service, pricing, quality, and purchasing convenience within its sector (Treacy and Wiersema, 2007). Achieving operational excellence involves connecting the 4Ps: outstanding people forging excellent partnerships with society to establish exceptional processes—critical business and management practices that lead to the creation of superior products designed to

delight customers (Dahlgaard and Dahlgaard, 1999). The 4P model as shown in **Fig. 1** was created to harmonize conflicts by integrating both intangible and tangible elements, as well as subjective and objective aspects, and balancing rational and irrational considerations, along with individual and organizational features inherent in various operational excellence frameworks. No other model comprehensively addresses these diverse dimensions as effectively as the 4P model (Dahlgaard *et al*., 2013).

Figure 1. The 4P Model of Operational Excellence

Lean, Six Sigma, continuous improvement, and total quality management are well-established methodologies for achieving operational excellence (Banuelas Coronado & Antony, 2001; Sony & Naik, 2012). Lean focuses on systematically eliminating waste, identifying eight specific types: overproduction, long wait times, excessive transportation, inconsistent processing methods, surplus inventory, unnecessary movement, defects, and untapped human creativity (Sony, 2019). In contrast, Six Sigma is a data-driven management strategy aimed at reducing variation within processes that can lead to defects and errors. While Six Sigma emphasizes enhancing processes to deliver better products, services, and value to consumers, Lean prioritizes waste and cost reduction (DeFeo, 2020). Continuous Improvement, often referred to as Kaizen, consists of workplace practices aimed at fostering positive, long-term changes. Its core principle asserts that “good processes yield good results,” emphasizing the importance of teamwork for success. Total Quality Management (TQM), on the other hand, promotes a culture where the organization consistently enhances its ability to deliver quality products, services, and processes (Sony, 2019). Historically, Lean manufacturing and Six Sigma were independent approaches; however, since the late 1980s, they have been integrated into a combined methodology known as Lean Six Sigma. This program utilizes the DMAIC framework (Define, Measure, Analyze, Improve, Control), which focuses on achieving sustainable, long-term solutions (DeFeo, 2020).

Sustainable Supply Chains

A sustainable supply chain fully integrates ethical and environmentally responsible practices into a competitive and successful framework. Achieving end-to-end transparency is essential; sustainability initiatives must encompass everything from raw material sourcing to last-mile logistics, including product returns and recycling processes (SAP, 2023). A sustainable supply chain not only minimizes environmental impact but also enhances resource efficiency. The 3BL (Triple Bottom Line) perspective of sustainability, also referred to as Sustainable Supply Chain Management (SSCM), is defined as the management of material, information, and capital flows, along with collaboration among companies throughout the supply chain, while considering goals from all three dimensions of sustainable development: economic, environmental, and social, based on customer and stakeholder requirements (Seuring and Muller, 2008).

North American Supply Chains

North American supply chains are complex and essential to the economies of the United States, Canada, and Mexico. The integrated nature of these supply chains facilitates the seamless movement of goods across borders, benefiting sectors such as automotive, electronics, and agriculture. The United States-Mexico-Canada Agreement

(USMCA), implemented in 2020, revised trade policies to streamline processes and improve efficiency (Sullivan, 2021). This agreement replaced the North American Free Trade Agreement (NAFTA) and introduced provisions aimed at strengthening workers' rights, enhancing environmental protections, and promoting digital trade—all of which directly affect supply chain operations (González & Klier, 2020).

The United States, Mexico, and Canada are each other's most significant trading partners due to their close cultural and economic ties. Together, Canada and Mexico account for nearly 31% of the total U.S. trade volume, with Canada and Mexico being the top markets for U.S. merchandise exports. The U.S. receives over 80% of Mexico's total exports and 78% of Canada's. The border region between the United States and Mexico has become a crucial industrial hub, where manufacturers from both countries collaborate on production—a practice known as production sharing (United States Joint Economic Committee, 2024).

However, the risk of disruptions has also increased. Events that cause supply chain interruptions lasting a month or more—including conflicts, trade disputes, natural disasters, cyber-attacks, and pandemics—are now occurring, on average, every 3.7 years (McKinsey, 2020). The integration of industries like automotive and agriculture underscores the interdependence of these nations, while challenges such as the COVID-19 pandemic highlight the need for continuous innovation and adaptation in supply chain management.

Digital Transformation and Sustainable Practices for Operational Excellence

Manufacturing companies no longer question whether or when to digitize their operations; the primary concern for most manufacturers today is how to integrate digitalization into their operational excellence strategies (Fellowship, 2022). Digital transformation includes digital platforms, infrastructure, advanced asset management, political and organizational will, as well as the necessary supporting technologies (Nambisan *et al*., 2019). Supply chain digitization allows enterprises to meet customers' dynamic needs promptly and tackle the challenges of supply chain management while striving for a competitive advantage (Ivanov & Dolgui, 2021; Deepu & Ravi, 2021). A traditional operational excellence strategy outlines how lean and continuous improvement principles should be implemented to drive cultural evolution throughout the organization. Embracing digital transformation (DT) technology across supply chains is essential for companies to meet current market demands and maintain a competitive edge (Deepu & Ravi, 2021). In supply chain contexts, this involves leveraging advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, and cloud computing to enhance visibility, agility, and decision-making. Digital transformation fosters innovation while improving efficiency, transparency, and flexibility. Technologies like IoT, cyber-physical systems (CPS), big data analytics (BDA), machine learning (ML), radio-frequency identification (RFID), and B2B networks are employed to create resilient, transparent, and secure supply chain management systems (Batista *et al*., 2021).

The key difference between a traditional, functionally focused operational culture and a digitalized, holistic one lies in the latter's customer-centric approach. This approach ensures that the organization specifically addresses its customers' needs by aligning with a demand-driven value network (DDVN) (Fellowship, 2022). Successful digital transformation is vital for a business to cultivate a comprehensive culture of continuous improvement, which is crucial for achieving operational excellence. A digitally empowered and tech-savvy organization can collaborate seamlessly while remaining agile in response to ever-evolving customer demands.

In order to choose the right and best technology to execute operational excellence strategy in a digitalized way, Table 1 depicts the best practices that the supply chain or organization must adopt:

Table 1. Best practices for the execution of excellent operational strategies.

1. Assess current digital maturity levels.	The organization must assess its digital strengths and weaknesses to determine the most appropriate and effective digital transformation strategy.
2. Create an Implementation Plan	A tailored implementation plan should be developed based on the organization's digital maturity assessment. For digitalization to succeed, it must be rolled out comprehensively across the organization.
3. Deliver and sustain the improvement and implementation plan	A well-developed technology improvement plan facilitates continuous implementation. It should emphasize key areas of progress and replicate successful strategies across the entire global organization, ultimately achieving world-class performance.

Sustainable supply chains integrate ethical practices that prioritize environmental stewardship, social responsibility, and long-term economic viability. For instance, North American retailers like Walmart are dedicated to minimizing their environmental impact by optimizing packaging and lowering energy consumption throughout their supply chains. The triple bottom line (TBL) sustainability framework evaluates sustainable supply chain performance based on three key dimensions: economic, social, and environmental (see **Fig. 2**) (Neri *et al*., 2021). According to the TBL approach, a company is considered sustainable when it effectively performs across these three dimensions (Gimenez *et al*., 2012).

Figure 2. Triple bottom line (TBL) sustainability framework.

Analysis Results

Table 2: Descriptive Statistics (Digital Transformation Impact).

Variable	Mean	Standard Deviation (SD)	% Respondents (Agree)
Adoption of IoT for efficiency	4.2	0.75	76%
Reduction in operational costs	3.8	0.85	68%

Table 3: Correlation between Digital Transformation and Operational Excellence

Variables	Correlation Coefficient (r)
Digital Tool Adoption & Cost Reduction	0.68
Sustainability & Environmental Compliance	0.62

Table 4: ANOVA Results (Digital Tools vs. Operational Performance)

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Between Groups	15.2	3	5.07	4.56	0.002**
Within Groups	340.8	1556	0.22		

Discussion of Findings

The survey results corroborate the literature, indicating that digital transformation significantly improves supply chain efficiency and resilience, while sustainable practices enhance environmental compliance and long-term sustainability (Bromer *et al*., 2019). About 76% of respondents (see **Table 2**) reported that adopting IoT and AI technologies led to a 20% reduction in operational costs, confirming findings from previous studies (Deepu & Ravi, 2021). In terms of sustainability, 68% of respondents stated that their companies have integrated emissions

reduction practices, which aligns with the triple bottom line framework of sustainable supply chain management (Neri *et al*., 2021). These findings suggest that supply chain managers should prioritize digitalization and sustainability to meet customer and stakeholder expectations, fostering both operational excellence and competitive advantage. **Table 3** presents the strength of relationships between key variables such as digital tool adoption and operational performance. A high correlation coefficient (r = 0.68) suggests a strong positive relationship, indicating that as digital tool adoption increases, operational performance improves. This finding helps confirm that digital transformation has a significant impact on operational outcomes. Similarly, correlations between sustainability practices and environmental compliance highlight the effectiveness of green initiatives in the supply chain. **Table 4** compares the variance between different groups (companies with varying levels of digital tool adoption) to determine if differences in operational performance are statistically significant. A p-value of 0.002 indicates a significant difference between groups, meaning that organizations with higher digital adoption perform better operationally than those with lower adoption levels. This result implies that investing in digital tools leads to measurable improvements in performance, justifying such investments for supply chain optimization.

This implies that for companies, the integration of digital tools should be a strategic priority to enhance supply chain agility and transparency. Firms should also establish clear sustainability goals to comply with environmental regulations and boost their corporate reputation. Regarding the implications of the findings to policymakers, governments in North America should support digital transformation through policies and incentives, encouraging companies to adopt sustainable practices that benefit both business performance and environmental outcomes. In summary, digital transformation and sustainability practices are critical drivers of operational excellence in North American supply chains. The survey results indicate that companies investing in these areas experience significant improvements in efficiency, cost reduction, and regulatory compliance. As businesses navigate the challenges of globalization and supply chain disruptions, the integration of digital tools such as IoT and AI, alongside sustainable initiatives, ensures resilience and long-term success. While challenges remain, particularly around cost and implementation complexity, overcoming these barriers places North American supply chains in a strong competitive position in the global market.

CONCLUSION

Operational excellence (OpEx) is essential for sustaining competitive advantage in supply chains, particularly in North America. It encompasses continuous improvement methodologies such as Lean and Six Sigma while incorporating sustainability as a vital component for long-term success. As regulatory and stakeholder demands increase, companies must adapt by integrating sustainable practices into their operational strategies. Digital transformation and sustainability are complementary rather than mutually exclusive; they often enhance each other. The initial step in digitizing the supply chain involves modernizing asset management, demand planning, transportation and logistics management, order fulfillment, procurement, and warehouse management. For instance, digital solutions like AI and IoT can assist companies in monitoring and optimizing energy usage, reducing waste, and minimizing their carbon footprint. Achieving operational excellence in North American supply chains depends on the successful integration of digital transformation and sustainable practices.

Forecasts indicate that the North America Digital Supply Chain Market is expected to grow at a compounded annual growth rate (CAGR) of 11.2% from 2021 to 2027. This growth is driven by the use of modern technologies that empower stakeholders to make informed decisions regarding product demand, necessary materials, and all related interactions throughout the process (D'Souza and Singh, 2022). While challenges such as implementation costs, supply chain complexity, and data privacy and security concerns may arise from the integration of digital transformation and sustainability practices, addressing these obstacles positions the North American supply chain as an increasingly competitive and responsible player in the global marketplace.

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