



## **Digital transformation in Sales and Operations Planning: An Integrative Approach of People, Process, IT and Performance Metrics**

**1° LUIGI BARONI** - luigi.baroni@mail.polimi.it

POLITECNICO DI MILANO – POLIMI

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO – PUC-RIO

**2° DOMINIK NEUMANN** - doms.neumann@googlemail.com

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO – PUC-RIO

**3° LUIZ FELIPE RORIS RODRIGUEZ SCAVARDA DO CARMO** -

lf.scavarda@puc-rio.br

PONTIFÍCIA UNIVERSIDADE CATÓLICA DO RIO DE JANEIRO – PUC-RIO

**4° ANDREA SIANESI** - andrea.sianesi@polimi.it

POLITECNICO DI MILANO – POLIMI

**5° DANIEL LUIZ DE MATTOS NASCIMENTO** - danielmattos@ub.edu

UNIVERSITAT DE BARCELONA - UB

**ÁREA:** 02. LOGÍSTICA

**SUBÁREA:** 2.1 - GESTÃO DA CADEIA DE SUPRIMENTOS

**RESUMO:** *Digital transformation has become essential for organizations navigating today's complex environments, particularly within Operations and Supply Chain Management (OSCM), where Industry 4.0 technologies are reshaping how value is created and delivered. However, the application of digital transformation in Sales and Operations Planning (S&OP), a key integrative practice in OSCM, remains underexplored. Therefore, drawing on insights from both the literature and expert interviews, an integrated framework for S&OP digital transformation is proposed, anchored in the principles of Sociotechnical System Theory, underscoring the mutual interdependence of social and technical subsystems within organizations, advocating for their co-optimization rather than isolated development. The proposed framework synthesizes findings across the four core S&OP dimensions (i.e., People, Process, IT, and Performance Measurement), each representing facets of the social and technical subsystems. These dimensions are further structured into three analytical categories: opportunities, challenges, and solutions. This categorization is mapped into main conceptual elements, ensuring coherence with the theoretical underpinnings. The research captures the tangible implications of digital transformation as they unfold within each dimension, offering a nuanced view of how organizations can navigate complexity and drive value through integrated planning. This sociotechnical lens offers a robust foundation for understanding digital transformation in S&OP and opens promising avenues for future research into resilient and adaptive organizational models.*

**PALAVRAS-CHAVES:** *Supply Chain; Industry 4.0; Data-driven decision-making; Sociotechnical System Theory.*

## 1. INTRODUCTION

Digital transformation has become a strategic imperative for organizations striving to remain competitive in today's volatile, uncertain, complex, and ambiguous (VUCA) environments (WAMBA-TAGUIMDJE et al., 2020). It entails the deep integration of Industry 4.0 (I4.0) technologies, such as Artificial Intelligence (AI), Interoperability, Big Data Analytics (BDA), cloud computing, Additive Manufacturing (AM), Blockchain and the Internet of Things (IoT), among others, into business operations, enabling fundamental shifts in how value is created and delivered (BAI et al., 2020; ZHENG et al., 2021; de Mattos Nascimento et al., 2024). These technologies are key enablers of the broader Industry 4.0 (I4.0) paradigm, which seeks to build intelligent, interconnected, and autonomous systems across the value chain. However, digital transformation goes beyond the implementation of new technologies. It requires comprehensive organizational change, including business processes redesign, the development of new skillsets, and the reconfiguration of governance and performance systems (VIAL, 2019; WAMBA-TAGUIMDJE et al., 2020), opening avenues for future researches within this holistic view underscoring the mutual interdependence of social and technical subsystems.

Although the domain of Operations and Supply Chain Management (OSCM) has been an important arena for digital transformation studies (BODENDORF et al., 2023; KHLIE et al., 2024; PAULL et al., 2025), its application is still underexplored in Sales and Operations Planning (S&OP), a significant supply chain integration practice (KALLA et al., 2025b). As a cross-functional process designed to align supply and demand planning with broader business strategy, S&OP plays a vital role in enabling organizational responsiveness, visibility, and strategic coordination (DANESE et al., 2017; GRIMSON & PYKE, 2007; THOMÉ et al., 2012). By integrating inputs from different business functions, S&OP helps to translate strategic objectives into actionable, feasible operational plans (WAGNER et al., 2013).

Despite its strategic importance, traditional S&OP practices often rely on outdated tools, such as spreadsheets, manual data consolidation, and fragmented communication channels, which severely limit responsiveness and data-driven decision-making in dynamic environments (JONSSON et al., 2021; KALLA et al., 2025a). In response, there is growing interest in digitally transforming S&OP using technologies such as predictive analytics, Machine Learning (ML), digital twins, and cloud-based collaboration systems (SENGUPTA & DREYER, 2023; XU et al., 2021). However, the implementation of such technologies in S&OP remains fragmented. Many organizations struggle to scale beyond isolated pilot projects due to a lack of integrated frameworks that address both technological enablers and the broader organizational context (BUSHUEVA & AFANASYEV, 2024; JONSSON et al., 2021). Existing S&OP maturity

models offer useful guidance, but often emphasize digital readiness or IT capability without adequately considering the socio-technical nature of transformation (DANESE et al., 2017; GRIMSON & PYKE, 2007; WAGNER et al., 2013).

In general, successful S&OP implementation requires organizations to address four interdependent dimensions: People, Processes, Information Technology (IT), and Performance Measurement (DANESE et al., 2017; KALLA et al., 2025a; KREUTER et al., 2021). The People dimension refers to leadership, skills, and organizational culture necessary to drive collaboration and commitment across functions. The Process dimension encompasses the structured workflows, communication mechanisms, and alignment practices that govern the S&OP cycle. IT supports planning activities through data integration, analytics, and system automation, serving as the digital foundation of the process. Finally, Performance Measurement involves the use of Key Performance Indicators (KPIs), dashboards, and feedback loops to monitor progress and ensure continuous improvement. These dimensions are interconnected and must evolve in unison to enable a mature and effective S&OP capability (DANESE et al., 2017; KALLA et al., 2025a). They also matter critically in the context of digital transformation, which does not merely affect the IT dimension but requires deep organizational alignment across all dimensions. For instance, the implementation of AI in S&OP may create opportunities for automation and forecasting but also demands new analytical skills (People), redesigned planning workflows (Processes), and adaptive KPI structures (Performance Measurement) (JAZAIRY et al., 2024). Therefore, digital transformation in S&OP is not only a technical initiative but a complex socio-technical change process.

This perspective aligns with Sociotechnical Systems Theory (EBY et al., 2000), which emphasizes that sustainable organizational transformation requires a joint view of social and technical subsystems. Neglecting one dimension can lead to inefficiencies or failure. Moreover, research on organizational change and digital shows that firms must identify not only what technologies to adopt, but also what opportunities and challenges arise across organizational layers and how they can be addressed (VIAL, 2019). Thus, the aim of this research paper is to build a holistic framework for digital transformation in S&OP, it is required to explore, in each dimension, the opportunities enabled by digital technologies, the challenges that emerge during implementation, and the solutions that can mitigate these barriers. Such a structured approach provides a practical roadmap for organizations moving toward S&OP 4.0, a state of integrated, intelligent, and resilient planning supported by digital innovation and organizational alignment.

This study aims to address this research gap by developing an integrative framework for digital S&OP transformation, focusing on the interplay between technological advancements and organizational dimensions. Thus, it seeks to answer the following Research Questions (RQ):

- RQ 1: Which digital technologies can be leveraged in S&OP to drive comprehensive transformation, and what opportunities do they present across the four key dimensions: People, Processes, Technology, and Performance Measurement?
- RQ 2: What challenges emerge within each of these dimensions during the adoption of digital technologies in S&OP, and what solutions can be applied to effectively address them?

By answering these questions, the study offers a theoretically grounded and practically relevant framework for guiding S&OP digital transformation.

The next section of the paper presents its theoretical background, followed by the research methodology and the findings, which introduce the proposed framework. The final section offers the authors' conclusions along with suggestions for future research.

## **2. THEORETICAL BACKGROUND**

The current body of literature on S&OP emphasizes that its successful implementation requires a holistic and integrated approach encompassing four interdependent dimensions: People, Process, IT, and Performance Measurement (DANESE et al., 2017; THOMÉ et al., 2012; WAGNER et al., 2013). These dimensions collectively shape an organization's ability to align strategic objectives with operational execution. Their integration is essential, as S&OP functions at the nexus of human judgment, standardized processes, digital capabilities, and feedback-driven performance management. Neglecting any one of these dimensions can result in systemic weaknesses that compromise the overall effectiveness of the planning process.

The People dimension comprises leadership support, skills and competencies, and organizational culture. Leadership plays a pivotal role in driving S&OP by providing a path, fostering cross-functional collaboration, and ensuring commitment across hierarchical levels. Skills and competencies refer to the technical and interpersonal abilities required for effective forecasting, planning, and coordination across departments (ANTUNES et al., 2020). Organizational culture, encompassing shared values, norms, and behaviors, influences the openness to change, level of accountability, and willingness to engage in collaborative decision-making (DANESE et al., 2017), critical for sustaining an effective S&OP.

The Process dimension refers to the structured set of activities and workflows that govern the execution of the S&OP cycle. It includes key elements such as the design and discipline of the

S&OP cycle structure, mechanisms for effective communication and collaboration, and the degree of cross-functional alignment. A clearly defined cycle structure ensures consistency and cadence in planning activities (THOMÉ et al., 2012), while robust communication and collaboration practices facilitate the timely exchange of information across business functions (KREUTER et al., 2021). Cross-functional alignment, in turn, is essential for ensuring that planning decisions reflect a unified organizational perspective (LAPIDE, 2005).

The IT dimension serves as the digital backbone of modern S&OP. It encompasses elements as advanced analytical, planning tools, data integration and data quality management. Analytical and planning systems, ranging from demand forecasting software to scenario planning and optimization tools, enhance the accuracy, speed, and responsiveness of the S&OP process (GRIMSON & PYKE, 2007). Effective data integration ensures that information is consolidated into a single, coherent view, while data quality is essential for generating reliable insights and sound planning decisions (WAGNER et al., 2013). Together, these technological capabilities provide the basic infrastructure for a responsive, transparent, and scalable S&OP.

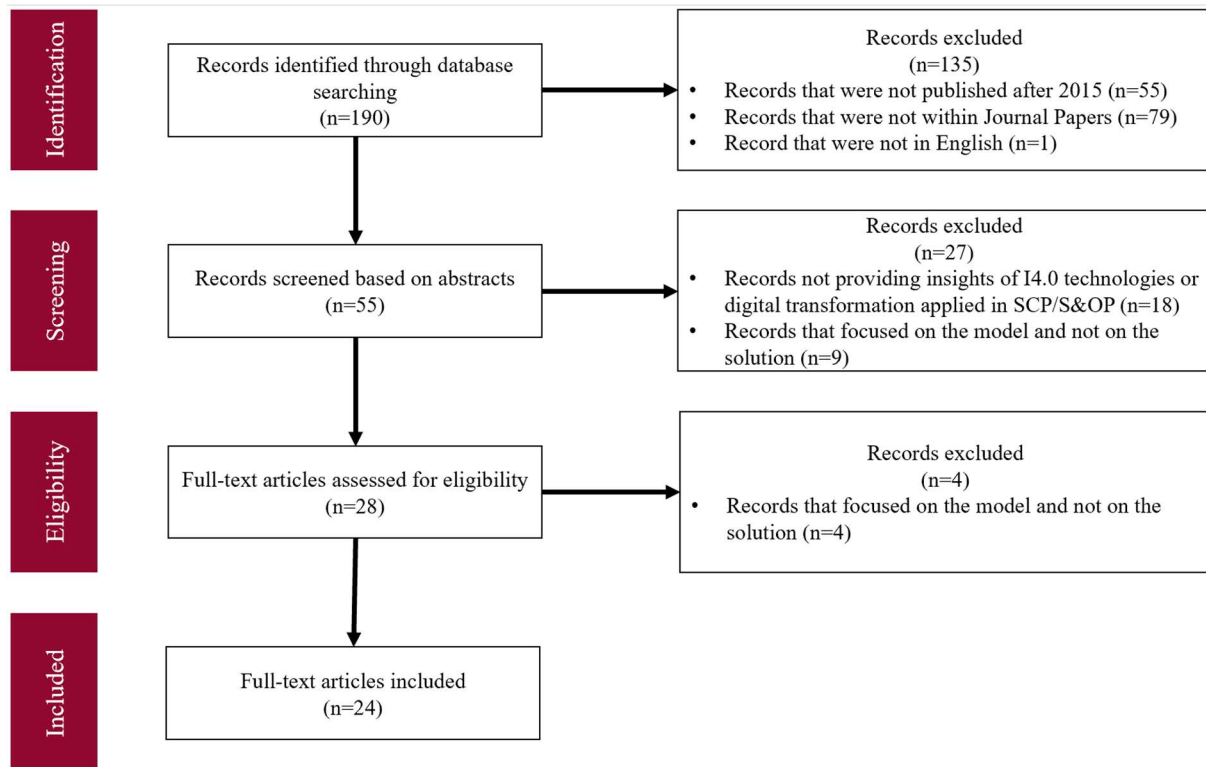
The Performance Measurement dimension provides the framework for monitoring, evaluating, and continuously improving the S&OP. It includes key elements as performance indicators (KPIs and metrics), dashboards, and action plans. Well-defined KPIs and metrics enable organizations to assess the effectiveness and efficiency of different planning activities (WAGNER et al., 2013). Dashboards serve as visual tools that consolidate and communicate performance data in a timely and accessible manner, supporting informed decision-making (THOMÉ et al., 2012). Action plans translate performance insights into concrete initiatives, ensuring that deviations from targets are addressed systematically and that continuous improvement is embedded in the S&OP process (KREUTER et al., 2021).

The interdependence of these dimensions explains why S&OP implementations often struggle when approached piecemeal (GRIMSON & PYKE, 2007). Advanced analytics tools (IT) generate little value without users skilled in interpretation (People) or processes to act on insights (Process). Similarly, meticulous process designs fail when unsupported by enabling systems (IT) or accountability mechanisms (Performance Measurement). Successful organizations therefore approach S&OP as an integrated system where capabilities across all four dimensions mature in concert - an insight supported by longitudinal research showing that balanced development of these pillars correlates strongly with S&OP effectiveness (DANESE et al., 2017; THOMÉ et al., 2012). This systemic perspective informs the framework's structure and guides its practical application for digital transformation.

### 3. METHOD

This study adopts a multimethod approach, combining a scoping review with expert interviews to ensure both theoretical rigor and practical relevance. The scoping review maps the breadth and depth of existing literature on digital transformation in S&OP, making it particularly well-suited for this dynamic and interdisciplinary field where conceptual boundaries remain fluid (Arksey & O'Malley, 2005). It facilitates the identification of relevant technologies, opportunities, challenges, and solutions across the key S&OP dimensions of People, Processes, IT, and Performance Measurement, which are then refined and validated through expert input. The scoping review follows Arksey and O'Malley's (2005) five-stage process and adheres to PRISMA guidelines (Moher et al., 2009) for transparency (as shown in Figure 1).

FIGURE 1 - Papers retrieved from the PRISMA perspective



Source: Adapted from Moher et al. (2009)

The review addresses the research questions posed in the introduction. The Scopus database was selected for its multidisciplinary coverage of peer-reviewed literature in OSCM with the following search string being applied: ( TITLE-ABS-KEY ( "sales and operations planning" OR "S&OP" OR "Supply Chain Planning" OR "Supply Chain Execution" ) AND TITLE-ABS-KEY ( "cyber physical systems" OR "internet of things" OR "IOT" OR "big data analytics" OR "BDA" OR "cloud computing" OR "artificial intelligence" OR "AI" OR "blockchain" OR "simulation and modeling" OR "visualization technology" OR "automation" OR "industrial robots" OR "additive manufacturing" OR "3D Printing" OR "5G" OR "Augmented Reality" OR "AR" OR "deep learning" OR "machine learning" OR "digital twin" OR "remote control" OR "remote monitoring" OR "wireless sensors" OR "virtual reality" OR "cyber security" ).

The string was intentionally designed to connect the concept of digital transformation with a broad scope of planning systems, including S&OP, Supply Chain Planning and Execution. The technologies included in the search draws on key studies by Zheng et al. (2021), Koh et al. (2019), and Tortorella et al. (2023), which synthesize relevant I4.0 technologies for OSCM.

The initial search returned 190 results. Three filters were applied: English-language, peer-reviewed journal articles from 2015–2025. Titles, abstracts, and full texts were screened by three researchers. After excluding papers focused solely on technical model improvements ( $n = 9$ ) or lacking adherence to digital transformation ( $n = 18$ ), 28 articles remained. Four articles were later excluded due to weak links between the technology and S&OP capabilities, resulting in a final dataset of 24 peer-reviewed articles. To enrich the findings, semi-structured interviews were conducted with three experts with both academic and practical S&OP backgrounds. Each session lasted around one hour and followed a structured protocol: presenting the initial framework, collecting feedback, and iteratively refining the model after each interview. The experts validated the identified technologies and contributed with empirical insights on their practical relevance, challenges, and potential solutions in each S&OP dimension of People, Process, IT, and Performance Measurement.

#### 4. RESULTS

Drawing on insights from both the literature and expert interviews, Figure 2 introduces an integrated framework for S&OP digital transformation, anchored in the principles of Sociotechnical System Theory. Therefore, it underscores the mutual interdependence of social and technical subsystems within organizations, advocating for their co-optimization rather than isolated development. The framework emphasizes the alignment of human-centric elements, such as organizational culture, workforce capabilities, and structural design, with Industry 4.0 technologies that are particularly relevant to S&OP. These include AI, ML, BDA, cloud computing, IoT, digital twins, blockchain, and advanced visualization tools. By integrating these components, the framework promotes the design of holistic solutions that not only enhance operational efficiency but also improve work-life quality. This sociotechnical lens offers a foundation for understanding digital transformation in S&OP and opens promising avenues for future research into resilient and adaptive organizational models.

The proposed framework synthesizes findings across the four core S&OP dimensions (i.e., People, Process, IT, and Performance Measurement), each representing facets of the social and technical subsystems. These dimensions are further structured into three analytical categories: opportunities, challenges, and solutions. This categorization is mapped to the conceptual

elements outlined in Section 2, ensuring coherence with the theoretical underpinnings. Therefore, it captures the tangible implications of digital transformation as they unfold within each dimension, offering a nuanced view of how organizations can navigate complexity and drive value through integrated planning. The subsequent sections delve deeper into these insights, providing a detailed exploration of the framework's practical relevance.

FIGURE 2 - A Multidimensional Framework for Digital Transformation in S&OP

DIMENSIONS	ELEMENTS	OPPORTUNITIES	CHALLENGES	SOLUTIONS
<b>PEOPLE</b>	<ul style="list-style-type: none"> <li>Leadership support</li> <li>Skills and competencies</li> <li>Organizational culture</li> </ul>	<ul style="list-style-type: none"> <li>Enhanced collaboration via digital tools</li> <li>Improved data-driven decision making</li> </ul>	<ul style="list-style-type: none"> <li>Resistance to change</li> <li>Digital skills gap</li> <li>Siloed thinking and ownership</li> <li>Lack of executive sponsorship</li> </ul>	<ul style="list-style-type: none"> <li>Change management programs</li> <li>Targeted digital training</li> <li>Cultural transformation</li> </ul>
<b>PROCESSES</b>	<ul style="list-style-type: none"> <li>S&amp;OP process design</li> <li>Communication &amp; Collaboration</li> <li>Cross-functional alignment</li> </ul>	<ul style="list-style-type: none"> <li>Shorter and faster planning cycles</li> <li>Real-time data access</li> <li>Improved demand/supply alignment</li> </ul>	<ul style="list-style-type: none"> <li>Misalignment across functions</li> <li>Information bottlenecks</li> </ul>	<ul style="list-style-type: none"> <li>Digital governance</li> <li>Integrated business planning</li> <li>Process automation</li> </ul>
<b>INFORMATION TECHNOLOGY</b>	<ul style="list-style-type: none"> <li>Advanced planning and analytics systems</li> <li>Data integration &amp; quality</li> </ul>	<ul style="list-style-type: none"> <li>Real-time visibility</li> <li>Advanced analytics</li> <li>Automated planning and decision support</li> </ul>	<ul style="list-style-type: none"> <li>High integration effort</li> <li>Data silos and poor quality</li> <li>Technological legacy constraints</li> </ul>	<ul style="list-style-type: none"> <li>Cloud solutions</li> <li>AI/ML-augmented planning platforms</li> <li>Robust data governance frameworks</li> </ul>
<b>PERFORMANCE MEASUREMENT</b>	<ul style="list-style-type: none"> <li>KPIs/metrics</li> <li>Dashboards</li> <li>Action plans</li> </ul>	<ul style="list-style-type: none"> <li>Continuous monitoring</li> <li>Fact-based insights</li> <li>Intelligent/Smart visualization</li> </ul>	<ul style="list-style-type: none"> <li>Siloed or irrelevant metrics</li> <li>Lack of benchmarking</li> <li>Inadequate validation of KPIs</li> </ul>	<ul style="list-style-type: none"> <li>Strategy-aligned and dynamic KPI frameworks</li> <li>AI-powered dashboards</li> <li>Regular metric validation</li> <li>Post-cycle debriefing and control mechanisms</li> </ul>

Source: The authors

#### 4.1 PEOPLE

The digital transformation of S&OP significantly reshapes the People dimension, emphasizing human and organizational capabilities required for successful technology adoption. Tools as advanced analytics, AI, and cloud-based platforms enhance cross-functional coordination and support data-driven decision-making. These technologies provide real-time insights and predictive capabilities, reducing reliance on intuition and improving forecast accuracy (SCHLEGEL et al., 2021; WAMBA-TAGUIMDJE et al., 2020). As Expert 3 notes, this is essential for responding dynamically to market changes and disruptions. Digital collaboration tools also help break down silos by enabling shared workspaces, fostering transparency, mutual understanding, and alignment across planning processes (GAHM, 2020).

However, several challenges complicate implementation. Resistance to change is common, as

employees may fear automation or job loss, often reverting to manual processes and undermining digitalization (JAZAIRY et al., 2024). A significant barrier is the digital skills gap, many employees lack the analytical and technical expertise needed for tools such as AI-driven forecasting or scenario modeling (PANWAR et al., 2022). Expert 2 notes that limited digital literacy often prevents organizations from realizing the full potential of advanced systems. Siloed thinking and unclear roles also hinder collaboration, especially when responsibilities are fragmented and decision rights ill-defined (HE et al., 2020). Lastly, as Expert 3 emphasizes, without strong top management support, digital initiatives may lack strategic relevance, leading to weak funding and low buy-in.

To address these issues, the framework proposes targeted interventions. Change management programs are essential to overcome resistance and promote behavioral shifts (GAHM, 2020; XU et al., 2021). These must go beyond basic training and include clear communication of the strategic value of digital tools, addressing concerns about job roles and authority in the digital context, as Expert 1 highlights. Targeted training programs are also critical to close the digital skills gap. Schlegel et al. (2021) stress the importance of human–AI collaboration, while Panwar et al. (2022) and Bodendorf et al. (2023) emphasize building both technical and managerial capabilities. Expert 3 adds that especially top managers need digital skills to lead by example and to meet their evolving strategic-technological responsibilities. Finally, building a digital-ready culture is vital. Without psychological safety, openness to experimentation, and willingness to share knowledge across functions, even the best systems will underperform (HE et al., 2020; PANWAR et al., 2022). Expert 2 underscores that such a culture fosters the trust and collaboration essential to S&OP success.

## **4.2 PROCESSES**

The Processes dimension represents the backbone of the S&OP cycle, as it governs how information flows, how decisions are made, and how cross-functional teams coordinate activities. Digital transformation offers a wealth of opportunities to optimize these processes by increasing their agility, responsiveness, and intelligence. A key opportunity enabled by digital technologies is the acceleration of planning cycles. Traditionally, S&OP operates on monthly cadences, often too slow to respond to today’s volatile markets (KALLA et al., 2025b). Expert 2 emphasizes that digital tools streamline workflows and reduce time spent on manual data collection and reconciliation, enabling a shift toward shorter, more frequent planning intervals. This transition supports continuous planning and rolling forecasts. Jazairy et al. (2024) further reinforce that such capabilities enable organizations to move from a reactive to a proactive posture, anticipating and mitigating disruptions before they materialize. Another

significant benefit is real-time data access and integration. IoT devices and Digital Twins can collect operational data across the supply chain in real time, while AI and ML process this data to generate actionable insights. This allows for adaptive, data-driven planning and dynamic demand forecasting (DOLGUI & IVANOV, 2025; HE et al., 2020; VLACHOS & REDDY, 2025). Blockchain adds another layer of trust and transparency by creating tamper-proof records of transactions and commitments (RAHMANZADEH et al., 2020).

Digital transformation also enhances demand-supply alignment by providing end-to-end visibility across departments and partners. With shared digital platforms and advanced analytics, organizations can synchronize customer demand signals with supply capabilities more precisely (PATTNAIK et al., 2024; SCHLEGEL et al., 2021). Expert 3 points out that particularly capacity alignment benefits from simulation and optimization tools, which assess constraints and explore alternative planning scenarios rapidly.

Despite these advantages, several challenges hinder the effectiveness of a digital S&OP. One persistent issue is misalignment across functions, where departments operate in silos, each following different objectives and planning logic. Such fragmentation undermines the consensus-building process of S&OP and leads to inconsistent decisions (PAULL et al., 2025). A related issue are information bottlenecks, where data is not readily available or fails to reach the right stakeholders in time (HE et al., 2020). These problems are exacerbated by legacy systems, informal communication channels, and a lack of standardized planning practices.

To tackle these challenges, the framework proposes several integrated solutions that directly mitigate the root causes of inefficiency and fragmentation. First, digital governance structures can realign the planning process by establishing clear roles, responsibilities, and decision rights across all functions involved in S&OP (Expert 1). Such structures reduce ambiguity and enable faster resolution of conflicts, particularly when supported by shared digital platforms. Governance mechanisms also standardize data usage and process steps, thus addressing the problem of functional misalignment and conflicting priorities. Second, Expert 1 and Paull et al. (2025) emphasize the value of automated global planning platforms that digitize and orchestrate all phases of the S&OP process. These platforms serve as a single source of truth and break down information silos by integrating data from multiple departments and geographies. With embedded AI and ML capabilities, such systems support decision-making and recommend optimized plans in real time. This directly tackles information bottlenecks and enables synchronized, cross-functional responses to demand and supply changes (Expert 2). Third, process automation emerges as a powerful solution to reduce inefficiencies and human error in routine planning activities. Automation is made possible by IoT and BDA, which feed real-time

inputs into planning engines. AI-powered process mining tools further support automation by mapping current workflows, identifying delays or redundancies, and recommending improvements (HE et al., 2020). In this way, automation addresses the resource drain caused by manual planning tasks and ensures consistency and speed throughout the S&OP cycle.

### 4.3 INFORMATION TECHNOLOGY

The IT dimension forms the backbone of digital S&OP transformation, enabling the collection, integration, analysis, and use of data for informed decision-making. Rather than serving as a support function, IT is a key enabler for cross-functional coordination and intelligent planning. One of the most impactful opportunities lies in real-time visibility across the value chain. Technologies like IoT, RFID, and cloud-based monitoring provide up-to-date information on demand, production, and inventory (DOLGUI & IVANOV, 2025; SCHLEGEL et al., 2021; VLACHOS & REDDY, 2025). This allows planners to react swiftly to disruptions and adapt plans dynamically (DOLGUI & IVANOV, 2025; SENGUPTA & DREYER, 2023). A second opportunity stems from advanced analytics and AI, which enhance forecasting, scenario planning, and decision support (SCHLEGEL et al., 2021). ML can uncover hidden patterns, simulate decisions, and optimize planning outcomes (PAULL et al., 2025). Expert 3 emphasizes that such tools shift S&OP from backward-looking to proactive planning. Additionally, automated decision support systems reduce manual work by autonomously generating plans, detecting deviations, and recommending responses (PAULL et al., 2025; SANKARAN et al., 2024; XU et al., 2021).

However, key challenges remain. A major barrier is the integration effort needed to connect fragmented systems across functions. Many firms rely on incompatible legacy systems, which complicate digital upgrades (PANWAR et al., 2022; Expert 2). Relatedly, data silos and poor data quality impede unified visibility. Fragmented datasets, inconsistent formats, and outdated records hinder analytics (HE et al., 2020; RAHMANZADEH et al., 2020). As Expert 1 notes, even advanced algorithms cannot compensate for bad data. Expert 3 adds that isolated ERP systems make consolidation especially heavy. Moreover, legacy IT infrastructure often lacks the scalability and performance required for real-time analytics (BODENDORF et al., 2023). To address these issues, the framework proposes three interrelated solutions. First, scalable cloud platforms enable centralized data access, real-time sharing, and seamless integration across departments and partners (GAHM, 2020; Expert 2). This helps eliminate silos and supports cross-functional collaboration. Second, AI/ML-enhanced planning platforms embed intelligence into the S&OP process, allowing predictive modeling, scenario simulations, and automated recommendations. These tools enhance decision speed, accuracy, and

responsiveness (KHLIE et al., 2024; Expert 2). Third, implementing a robust data governance framework ensures data quality and consistency. This includes defining ownership, quality standards, validation rules, and access protocols, which are essential for harmonizing inputs across systems (JAZAIRY et al., 2024; Expert 2).

#### **4.4 PERFORMANCE MEASUREMENT**

This dimension plays a crucial role in ensuring that S&OP processes are not only well-executed but also continuously improved. Digital transformation brings several important opportunities in this area. First, the integration of advanced technologies enables continuous monitoring of KPIs across the planning cycle, facilitating real-time tracking and more agile decision-making (DOLGUI & IVANOV, 2025; SENGUPTA & DREYER, 2023). This allows organizations to respond quickly to deviations and emerging risks (PATRNAIK et al., 2024). Second, digital tools enhance fact-based insights, replacing gut-feeling decisions with evidence-based evaluations derived from integrated data sources (SCHLEGEL et al., 2021). Third, intelligent and interactive visualizations, such as AI-powered dashboards, make performance data more accessible and actionable for decision-makers across functional levels. These visualizations support transparency and help align teams around shared performance goals (Expert 2).

Despite these advantages, organizations face several challenges in leveraging digital performance measurement effectively. One major issue is the presence of siloed or irrelevant metrics, where different departments track performance independently, often using outdated or non-comparable indicators (HE et al., 2020; Expert 1). Another challenge is the lack of external or internal benchmarking, which limits the organization's ability to contextualize its performance or identify improvement potential (Expert 1). Additionally, poor metric validation, including a lack of standardized data definitions and inconsistent measurement intervals, can distort the accuracy and reliability of reported outcomes (Expert 2).

To overcome these barriers, the framework introduces a set of interrelated solutions. Establishing strategy-aligned and dynamic KPI dashboards helps ensure that performance metrics reflect overarching business objectives and evolve in response to changing market conditions. This can support cross-functional alignment and make it easier to prioritize what matters most at different maturity stages of S&OP (KHLIE et al., 2024; Expert 3). AI-powered dashboards further enhance monitoring by generating automated insights, pattern recognition, and proactive alerts, thereby reducing manual reporting burdens and enabling predictive oversight (KHLIE et al., 2024; Expert 2). Regular metric validation routines, including audits and cross-checks, help maintain consistency and reliability over time. Lastly, structured controlling and debriefing processes embedded into each S&OP cycle ensure according to

Expert 3 that performance feedback is systematically analyzed and translated into process improvements, closing the loop between planning and execution.

## 5. CONCLUSIONS

Digital transformation represents a pivotal shift in how organizations approach S&OP, moving from traditional, siloed processes toward an integrated, intelligent, and agile paradigm. This study has developed a comprehensive framework that synthesizes the opportunities, challenges, and solutions associated with digital S&OP transformation across four critical dimensions: People, Processes, IT, and Performance Measurement. By leveraging advanced technologies, such as AI, IoT, cloud computing, and advanced analytics, organizations can enhance cross-functional collaboration, accelerate planning cycles, and enable data-driven decision-making. However, the findings underscore that technological adoption alone is insufficient; success hinges on aligning digital tools with organizational capabilities, governance structures, and cultural readiness. The People dimension highlights the necessity of leadership commitment, change management, and upskilling to overcome resistance and foster a digital-first mindset. Process improvements demand governance frameworks and automation to break down silos and enable real-time responsiveness. IT must prioritize scalable, integrated systems with robust data governance to ensure accuracy and accessibility. Finally, Performance Measurement must evolve toward dynamic, strategy-aligned KPIs supported by AI-driven analytics to enable continuous improvement. Crucially, these dimensions are interdependent; neglecting any one can undermine the entire transformation effort.

This research contributes a theoretically grounded and practitioner-relevant framework to guide organizations in navigating the complexities of digital S&OP transformation. Research findings emphasize a balanced, systemic approach, one that harmonizes technological innovation with organizational change, to unlock the full potential of digital S&OP. As businesses operate in increasingly volatile environments, the ability to integrate digital and human capabilities will distinguish resilient, adaptive enterprises from those constrained by legacy inefficiencies. The journey toward digital S&OP is not merely a technological upgrade but a strategic evolution, demanding vision, investment, and persistence to achieve enduring competitive advantage.

The findings suggest that digital transformation in S&OP should integrate both social and technical subsystems, highlighting potential avenues for future research through the lens of Sociotechnical System Theory. Additionally, subsequent studies could empirically assess the framework's applicability across industries or explore how emerging technologies, such as generative AI, can enhance tactical planning processes.

**ACKNOWLEDGMENTS:** The authors convey their gratitude to the experts who contributed to the panel, as well as to the following research funding agencies: CAPES, CNPq and FAPERJ.

## REFERENCES

- Antunes, S., Okano, M., Ribeiro, R. (2020). Sales and Operations Planning (S&OP) and Digital Transformation: A Narrative Review. *Research, Society and Development*, 9, e746986506.
- Arksey, H., O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, 8(1), 19–32.
- Bai, C., Dallasega, P., Orzes, G., Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics*, 229, 107776.
- Bodendorf, F., Dentler, S., Franke, J. (2023). Digitally enabled supply chain integration through business and process analytics. *Industrial Marketing Management*, 114, 14–31.
- Bushueva, L. I., Afanasyev, V. B. (2024). Management of digital transformation of the sales and operations planning process in an organization. *Corporate Governance and Innovative Development of the Economy of the North* (4), 1–12.
- Danese, P., Molinaro, M., Romano, P. (2017). Managing evolutionary paths in Sales and Operations Planning: key dimensions and sequences of implementation. *International Journal of Production Research*, 56, 1–18.
- Dolgui, A., Ivanov, D. (2025). Internet of behaviors: conceptual model, practical and theoretical implications for supply chain and operations management. *International Journal of Production Research*, 63(1), 1–8.
- Eby, L., Sinoway, B., Parisi, A. (2000). Socio-Technical Systems Approach to Work Team Design. In M. Beyerlein (Ed.), *Work Teams: Past, Present and Future* (pp. 115–129).
- Gahm, C. (2020). A conceptual framework for cloud-based advanced planning systems. *Journal of Decision Systems*, 32, 1–30.
- Grimson, J., Pyke, D. (2007). Sales and operations planning: An exploratory study and framework. *The International Journal of Logistics Management*, 18, 322–346.
- He, L., Xue, M., Gu, B. (2020). Internet-of-things enabled supply chain planning and coordination with big data services: Certain theoretic implications. *Journal of Management Science and Engineering*, 5(1), 1–22.
- Jazairy, A., Shurrab, H., Chedid, F. (2024). Impact pathways: walking a tightrope-unveiling the paradoxes of adopting artificial intelligence (AI) in sales and operations planning. *International Journal of Operations & Production Management*, 45, 1–27.
- Jonsson, P., Kaipia, R., Barratt, M. (2021). The future of S&OP: dynamic complexity, ecosystems and resilience. *International Journal of Physical Distribution & Logistics Management*, 56, 553–565.
- Kalla, C., Scavarda, L. F., Caiado, R., Hellingrath, B. (2025b). Adapting sales and operations planning to dynamic and complex supply chains. *Review of Managerial Science*. Advance online publication. <https://doi.org/10.1007/s11846-024-00756-y>
- Kalla, C., Scavarda, L.F., Hellingrath, B. (2025a). Integrating supply chain risk management activities into sales and operations planning. *Review of Managerial Science*, 19, 467–97.
- Khlie, K., Benmamoun, Z., Jebbor, I., Serrou, D. (2024). Generative AI for enhanced operations and supply chain management. *Journal of Infrastructure, Policy and Development*, 8, 6637.
- Koh, L., Orzes, G., Jia, F. (2019). The fourth industrial revolution (Industry 4.0): technologies disruption on operations and supply chain management. *International Journal of Operations & Production Management*, 39(6/7/8), 817–828.

- Kreuter, T., Kalla, C., Scavarda, L., Thomé, A., Hellingrath, B. (2021). Developing and implementing contextualised S&OP designs: an enterprise architecture management approach. *International Journal of Physical Distribution & Logistics Management*, 51,634-55.
- Lapide, L. (2005). Sales and operations planning Part III: a diagnostic model. *The Journal of Business Forecasting*, 24(1), 13–16.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 6(7), e1000097.
- Panwar, R., Pinkse, J., Marchi, V. de (2022). The Future of Global Supply Chains in a Post-COVID-19 World. *California Management Review*, 64(2), 5–23.
- Pattnaik, S., Liew, N., Kures, A., Pinsky, E., Park, K. (2024). Catalyzing Supply Chain Evolution: A Comprehensive Examination of Artificial Intelligence Integration in Supply Chain Management. *Engineering Proceedings*(68), 57–66.
- Paull, S., Bubak, R., & Stuckenschmidt, H. (2025). Machine Learning for Master Production Scheduling: Combining probabilistic forecasting with stochastic optimisation. *Expert Systems with Applications*, 271, 126586.
- Rahmanzadeh, S., Pishvaei, M. S., Rasouli, M. R. (2020). Integrated innovative product design and supply chain tactical planning within a blockchain platform. *International Journal of Production Research*, 58(7), 2242–2262.
- Sankaran, G., Palomino, M. A., Knahl, M., Siestrup, G. (2024). Towards a System Dynamics Framework for Human–Machine Learning Decisions: A Case Study of New York Citi Bike. *Applied Sciences*, 14(22), 1–31.
- Schlegel, A., Birkel, H., Hartmann, E. (2021). Enabling integrated business planning through big data analytics: a case study on sales and operations planning. *International Journal of Physical Distribution & Logistics Management*, ahead-of-print.
- Sengupta, S., Dreyer, H. (2023). Realizing zero-waste value chains through digital twin-driven S&OP: A case of grocery retail. *Computers in Industry*, 148, 103890.
- Thomé, A., Scavarda, L., Fernandez, N., Scavarda, A. (2012). Sales and operations planning: A research synthesis. *International Journal of Production Economics*, 138, 1–13.
- Tortorella, G. L., Saurin, T. A., Hines, P., Antony, J., Samson, D. (2023). Myths and facts of industry 4.0. *International Journal of Production Economics*, 255, 108660.
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28.
- Vlachos, I., Reddy, P. (2025). Machine learning in supply chain management: systematic literature review and future research agenda. *International Journal of Production Research*, 1–30. Ahead of print.
- Wagner, S., Ullrich, K., Transchel, S. (2013). The game plan for aligning the organization. *Business Horizons*, 57, 189–201.
- Wamba-Taguimdje, S.-L., Fosso Wamba, S., Jean Robert, K. K., Tchatchouang, C. E. (2020). Influence of Artificial Intelligence (AI) on Firm Performance: The Business Value of AI-based Transformation Projects.
- Xu, J., Pero, M., Ciccullo, F., Sianesi, A. (2021). On relating big data analytics to supply chain planning: towards a research agenda. *International Journal of Physical Distribution & Logistics Management*, 51, 656–682.
- Zheng, T., Ardolino, M., Bacchetti, A., Perona, M. (2021). The applications of Industry 4.0 technologies in manufacturing context: a systematic literature review. *International Journal of Production Research*, 59(6), 1922–1954.