An Evaluation of Strategic Digital Transformation Models in Supply Chain Management

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Abstract - **Digital Transformation has become an inevitable factor catering to the resilience and agility in supply chains. Even though researchers have explored the adoption of different technologies in multiple functionalities within supply chains, current literature lacks a holistic view of the digital transformation process of supply chains, which entails the strategic adoption of technologies in supply chain operations. This study evaluates the status of digital transformation literature in supply chain management, thereby contributing to the body of knowledge by providing a synthesized evaluation of the digital transformation models and frameworks developed by researchers. Findings show that the existing digital transformation models lack the ability to guide the process with a holistic view, and that scholarly work is dispersed across different stages of the strategy management process.**

Keywords – **Digital Transformation Models, Supply Chain, Digital Transformation Strategy, Digital Transformation Adoption**

I. INTRODUCTION

Researchers have thus far majorly focused on the utilization of specific technologies in specific functional processes in supply chains (SC). However, 'digitally transforming' operations entail much more than the integration of individual technologies within different functionalities, and usually involves "corporate strategy, organizational structure, human resources, business processes, and product structure and is designed to cope with dynamic changes in the business environment"[1]. Current literature lacks the study of this holistic view of adapting technology within the SC space, and calls for well-planned processes for digital transformation in order to avoid failures and disconnected technology adaptations in different stages of SC [2].

This study intends to evaluate digital transformation models presented by researchers in recent literature, and to identify related gaps, thereby guiding future researchers' work in digital transformation of supply chains. Digitally transforming supply chain operations is an inevitable task in the current landscape of operations and technology, hence, informed guidance is critical for organizations to make conscious strategic decisions.

The key contribution of this paper to the body of knowledge is the presentation of a synthesis of current work in digital transformation models in the supply chain landscape, providing an overview of the status of scholarly progress, highlighting the gaps and weaknesses that need to be addressed by researchers in future.

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II. METHODOLOGY

This paper can be categorized as a rapid review of existing literature, as insights are derived from the work of experts and researchers in the field. A rapid review is "a type of knowledge synthesis in which components of the systematic review process are simplified or omitted to produce information in a short period of time" [3].

The primary goal of this review was to identify models, frameworks or explicit strategies developed by researchers to guide the digital transformation process of supply chains. The study also contributes to providing a synthesized understanding of the different types of models, and the different stages of strategy development that have been covered by researchers.

Literature on existing evidence was summarized, using publications from journals that were ranked Q1 in Scopus, to maintain the high quality of the output of the synthesis. Publications were sought out between the period of 2020 – 2024, focusing on the most recent literature from the past five years. The literature search was carried out on IEEE Electronic Library, Web of Science, Scopus, ProQuest Central, and the Web of Science Core Collection. The search was limited to peer-reviewed journal articles, excluding review articles, retracted papers, and preprints. The search string 'digital transformation' AND (model* OR strateg*) AND 'supply chain' was used to extract literature. Initially, records were screened based on the evidence of the presence of an explicit model, framework or strategy for digital transformation and the focus on the digital transformation of overall supply chain processes or its decision-making aspect

A detailed analysis of relevance was conducted based on the content. Most of the extracted papers included the digitization of sub processes within the larger context of supply chains and providing sustainability perspectives. The presence of a self-developed model or framework was detected only in 5 papers, whereas 2 other papers presented digital transformation strategies.

The PRISMA of the literature screening process is given in Fig. 1 [4].

III. FINDINGS

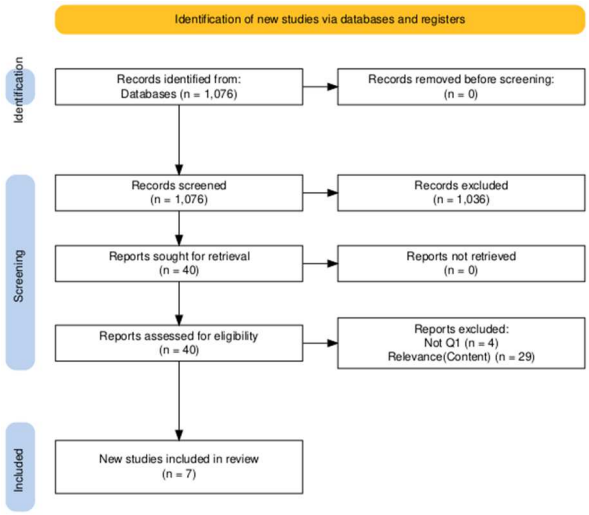

Fig. 1. Literature Screening Process

'Digital Transformation' is presented in research as a strategy which requires comprehensive actions taking a range of factors into consideration [5].

Hence, this paper looks at the process of Digital Transformation as a conscious decision taken by an organization, carried out in different stages similar to managing a strategy. The digital transformation models and frameworks presented in literature have been examined from a strategic perspective. Based on the nature of the models and frameworks presented in the selected literature, the different stages covered were categorized into 5 categories based on the strategic management process covered by [6, 7]. The stages include environmental analysis, strategy formulation, strategy evaluation/adoption, strategy implementation, and strategy monitoring and control.

Environmental analysis includes investigating the internal and external environments of the organization, including resources, capabilities and competencies [7]. The strategy formulation stage involves bringing elements such as the analysis, measures and investments, guidelines for central functions and strategic financial perspective into definitive form [6]. The strategy evaluation stage involves the assessment of strategic options, guidelines and realized strategies using defined criteria [6]. Strategy implementation involves the realization of intended strategies through executing the actionable plans[6]. The monitoring and control stage involves progress tracking, performance measurement and the updates made to the strategy based on feedback and other adaptations [6].

Given the interconnected nature of environmental analysis and strategy formulation stages as detailed in both studies, this study will consider environmental analysis as a component within the strategy formulation stage.

A. Strategy Development/Formulation

Birkel and Wehrle [5] have focused on how small and medium sized enterprises (SMEs) have tackled the digital transformation of supply chain processes, basing the findings on seven case studies from the manufacturing industry in Germany. The study has identified three distinct strategic approaches to digital transformation taken by the SMEs including a 'deliberate wait-and-see approach', small steps' and 'pragmatic subprocess optimization', often dependent on factors such as the availability of resources and their risk attitudes. The study has also identified five variables affecting the conscious choice of these strategic approaches, as the company's attitude about digital transformation, maturity of current analogous processes, the current ERP system's role, the company's strategy for addressing uncertainty, and their strategy for driving digital transformation consciously or unconsciously. Whereas the choice of this strategic approach would come first when defining an organization's take on digital transformation of its supply chain operations, the three approaches lack the ability to be generalized into contexts other than those of SMEs. It is also possible that these approaches do not exist in a mutually exclusive setting in larger scale organizations and public organizations. Hence, the categorization does not cater to presenting general guidance to non-SMEs to understand and decide their strategic take on the matter.

Yadav [8] has developed a framework for analyzing the role of digital technology in the health product supply chain. The conceptual framework can be identified as more customized to the supply chain context compared to that of Birkel and Wehrle [5]. This is given the use of the Supply Chain Operations Reference (SCOR) model and the Access Framework by Frost and Reich, in order to understand the integration of digital technologies with a process-oriented mindset. Yadav [8] has, however, presented work that consists of the identification of multiple case studies in the context of health product supply chains in low- and middle-income countries, that fall under each category of Plan, Source, Deliver and Enable in the SCOR framework. The Make and Return stages have been deliberately left out of the scope, and the study presents a collection of examples of digitized solutions within each of the other stages. The study has not gone to the extent of comparison of the case studies to identify common approaches or best-case practices and has left them in the same fragmented state. The study has also integrated the Access Framework within the developed conceptual model, thereby linking the digital initiatives to ultimate health goals such as availability, affordability, adoption and architecture. However, the division of digital implementations into different categories in the SCOR model could obscure the interdependencies and synergies among them. This results in overlooking the whole purpose of 'digital transformation' as a strategy that aims to take out the disconnectedness and fragmentation of technological implementations.

Assessment of the maturity level of current technology adoptions and organizational factors, also termed as the 'readiness assessment' can be identified in a few studies, considered in the initial stage of analysis in strategy development.

Yadav [8] has suggested the assessment of readiness across three dimensions for each process in the supply chain ahead of creating policy changes: technological and infrastructural readiness, organizational readiness, and environmental readiness. Within these factors such as foundational infrastructure, employee skill levels, political support, organizational structure, supplier and stakeholder capabilities, etc. are covered, similar to most of the factors presented by Birkel and Wehrle [5].

Weerabahu, et al. [9] have gone one step further and defined four stages of maturity for digital supply chain models, as traditional SC, internal digital SC, extended internal digital supply chain (DSC) and DSC ecosystem, using four criteria that mostly align with those of Yadav [8]. The criteria include I4.0 technologies and resources, supply chain strategy and planning, people, skill and competencies, and supply chain dynamic capabilities. However, it is noteworthy that the origin of the model stems from inspiration from studies focused on the manufacturing industry. Kırmızı and Kocaoglu [10] have presented a similar categorization of maturity levels as "awareness, pilot, engagement, SC integration and optimization", consistent with the observations of Weerabahu, et al. [9].

The cost component attached with digital transformation is considered to be a significant barrier limiting organizations from pursuing initiatives. Zhang, et al. [11]'s contribution to the body of knowledge on digital transformation in healthcare supply chains involves the introduction of three investment strategies: manufacturer-led investment, retailer-led investment and joint investment with cost-sharing, in dual-channel supply chains. Whilst benefits are presented in both models funded individually by the manufacturer or the retailer, the mathematical results imply that cost-sharing achieves the best level of coordination and balanced profits. However, this model has its limitations, provided that it is designed for a single manufacturer-single retailer relationship, thus limiting its applicability in real-world supply chains.

Seker and Aydin [12] have also presented a set of strategies that can be utilized to overcome the barriers faced in digitally transforming healthcare supply chains, mostly including tactics to manage the people component, such as skill development, incentives for top managers, using regulatory enforcements for labour and employment, and developing technical standards. Even though these strategies provide fundamental guidance to overcome major human barriers to digital transformation, other factors such as financial constraints are not addressed within these strategies.

The strategy formulation stage involves an internal and external analysis, as well as developing and evaluating strategic options [6, 7]. Based on the work conducted by researchers related to digital transformation in supply chains, few major tasks to be carried out in this stage can be identified, as presented in Fig. 2. The initial work required to be carried out by an organization that is strategically digitally transforming their supply chain can be narrowed down into four stages in the strategy

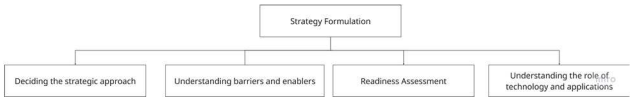

Fig. 2. Strategy formulation breakdown for digital transformation

formulation stage. This includes the decision of a strategic approach, gaining an understanding of the barriers and enablers to digital transformation based on related contextual factors, understanding the role of technology and its applications within the functionalities of the organization, and carrying out a digital readiness assessment to ensure the availability of the capacity and resources required to implement the digital transformation strategy.

B. Strategy Evaluation/Adoption

The strategy evaluation stage involves the assessment of strategic options, guidelines and realized strategies using defined criteria [6].

Weerabahu, et al. [9] have presented a framework for adopting digital SCs successfully, consisting of six major stages: "Assess AS-IS state, Define Objectives, Develop TO-BE vision, build a roadmap, Manage portfolio, and Successful adoption of Digital SC". Among the selected literature, this happens to be the only source of a complete overview of the steps required to digitally transform a SC. However, the framework fails to provide elaborate guidance to practitioners wanting to follow a roadmap to digitally transform SCs, or to consider domain-specific constraints and factors under each stage. The study does provide a set of enablers and challenges; however, future work includes the integration of these enablers and challenges to build a comprehensive framework specific to supply chains, considering factors such as 'readiness', catering to different maturity levels.

Mahmood, et al. [13] has used five criteria to prioritize between digital transformation strategies: "accelerating innovation, better decision making, end-to-end customer engagement, organizational flexibility and increase automation". These criteria have been used in the mathematical equations presented in the study in order to determine priorities, however, it is noteworthy that the choice of these criteria has not been backed by literature or any logical reasoning, and higher focus has been given to mathematical reasoning.

C. Strategy Implementation

Strategy implementation involves the realization of intended strategies through executing the actionable plans[6]. Birkel and Wehrle [5] have presented a bottom-up model for the organizational implementation of digital transformation within supply chains. The 3-stage model, detailing the initiation, design and execution phases also includes the tasks included within each of the stages, as well as the parties implementing the tasks. Tasks such as initiating the digital transformation process, spotting areas

TABLE I
SUMMARY OF DIGITAL TRANSFORMATION MODELS IN RESEARCH

Key Stage	Sub Processes	Studies
Strategy Development/Formulation	Deciding the strategic approach	[5]
	Understanding barriers and enablers	[9,11,12]
	Understanding the role of technology and applications	[8]
	Readiness Assessment	[5,8,9,10]
Strategy Adoption/ Decision	Sufficient scholarly work has not been carried out related to these stages to identify processes or stages comparing multiple studies.	[9,13]
Strategy Implementation		[5]
Strategy Monitoring/Control		No studies

where digital tools could be used to resolve operational pain points, architecting the solution, and implementing and coordinating the procedures cover a basic overview of the implementation process, which is generalizable to the implementation of digital transformation in any context. However, the model lacks the development of a connection specific to the supply chain processes, as well as the consideration of external factors such as human resistance, digital readiness, monitoring and adjustment, etc.

IV. DISCUSSION

Based on the categorization done under the strategy management process, a few key noteworthy observations can be made.

A. Weaknesses in current work:

Table 1 presents a summary of the breakdown identified in terms of the representation of different stages of strategy management in the digital transformation models presented by researchers in supply chain literature. Birkel and Wehrle [5]'s study has identified three main strategic approaches to digital transformation using 7 case studies: wait and see, small steps and pragmatic sub-process optimization, and has also presented 5 variables affecting the choice of a digital strategy approach. However, the insights, as well as the approaches are limited to the context of SMEs and lacks guidance to practitioners on how to decide on a strategic approach.

The 'Understanding barriers and enablers' phase has been covered in the work of Seker and Aydin [12], Weerabahu, et al. [9] and Zhang, et al. [11]. These studies collectively present a set of barriers and enablers identified that challenge and drive digital transformation. Zhang, et al. [11] provides different strategies to address the financial barriers with optimal investment strategies for digital transformation. However, the identified barriers, as well as enablers will differ based on the organization, industry and contextual factors. It will also depend on the digital readiness or maturity, and collective workarounds cannot be developed based on the individual barriers and enablers that have been identified.

Yadav [8]'s study can be identified as the only study among selected literature covering the phase of 'understanding the role of technology and applications' under the strategy formulation phase. The study uses the SCOR model and the Access framework to integrate digitization into supply chain processes. Whilst the model provides a process-oriented perspective, case studies have been provided for different stages of the SCOR model, lacking a synthesis of best-case practices across each stage, and the consideration of synergies and interdependencies between the blocks.

Birkel and Wehrle [5], Kırmızı and Kocaoglu [10], Weerabahu, et al. [9] and Yadav [8] have provided insights covering the 'readiness assessment' stage under strategy development. Although the studies outline digital maturity and readiness stages in different ways, they generally exhibit similar categorization features and overlap significantly in their core characteristics. The readiness assessments are comprehensively developed. However, none of the studies integrate it into the process of developing a digital transformation strategy/roadmap.

Mahmood, et al. [13] have provided 5 criteria used to prioritize digital transformation strategies for decision making under the strategy adoption/evaluation phase of integrating digital transformation into an organization's supply chain. Weerabahu, et al. [9] have laid down a 6-stage process for successful adoption of digital SCs. However, the criteria lack theoretical backing, as the study by Mahmood et al. focuses on the mathematical aspect of prioritization [10]. Weerabahu, et al. [9] has suggested a process that can be identified to be very general, lacking the customization to the supply chain process and not integrated with the elaborated steps to be followed within each of these stages, and the required guidance for practitioners based on their maturity levels.

Birkel and Wehrle [5] 's study can be identified as the sole scholarly outcome covering the Strategy Implementation stage of digital transformation. While the study has developed a 3-stage model covering the initiation, design and execution phases, the model does not take into consideration the firm's chosen strategy or the size and lacks the integration with all other factors that need to be considered during the implementation, other than IT resources.

B. Gaps in current work

It is noteworthy that none of the studies have covered the strategy monitoring and control stage, whereby the chosen digital transformation strategy is expected to be assessed against key performance indicators and reviewed. It is important that this stage is explored in future research, as it determines how the implementations are traced and

how the environment adapts or reacts to the strategies in place [6].

Also, the existing models presented in current research mostly fail to address contextual factors related to supply chains, and the domain it is involved in. The models also lack a holistic view that is integrated with organizational factors, people factors and environmental factors and fail to provide end-to-end guidance to practitioners interested in digitally transforming their supply chain operations. None of the studies provide a context-adaptable framework guiding practitioners through key decisions throughout the lifecycle of rolling out a digital transformation strategy in supply chain.

V. CONCLUSION

The development of digital transformation models in the field of supply chain is still at a nascent stage. Researchers have explored the possibility of developing models and frameworks to assist structured, strategic digital transformation. However, existing work is fragmented across multiple stages of creating and managing strategy. Current literature lacks a holistic view of all the factors and the strategic stages to be considered during the managerial process of formulating and implementing a digital transformation strategy for supply chains. Most of the existing models and frameworks fall under the strategy formulation stage, guiding the choice of strategic approach, understanding of internal capabilities and digital maturity, understanding the functional applications, enablers and barriers. The focus on guiding the decision-making process related to the digital transformation adoption and the implementation stages happen to be noticeably minimal, whereas the strategy monitoring and control phase for digital transformation is not covered by any studies within the supply chain literature.

The study paves the way for future studies to gain an understanding of the status of development of digital transformation models, and to rely on the existing models and frameworks to lay the groundwork to produce comprehensive digital transformation frameworks for supply chains, with a holistic view across the different stages of strategy management. Limitations of this study include the generalized lens on supply chain, without considering contextual implications brought forth by industry, supply chain functionality, and geographical factors. Future directions include the development of guidance frameworks for practitioners to digitally transform supply chain operations, integrating contextual factors and limitations across each stage of strategy management.

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