

A Digital Strategy Development Framework for Supply Chains

Abstract

Digitalisation has provoked the rapid proliferation of changes in the operational landscape, thus requiring prompt decision making across end-to-end supply chains. Notwithstanding the fact that technology is the epicentre of digital transformation, more often than not, organisations fail to effectively adopt innovative applications, harness their full potential and realise growth and competitiveness. Therefore, this research argues that a unique strategy formulation process is required to embrace digitalisation in manufacturing supply chains. However, within the context of manufacturing networks, strategy formulation approaches are limited. To this end, this research adopts a case study approach to extract tacit knowledge across twelve multinational companies within the theoretical boundaries of corporate strategy development. Research findings and a theoretically derived framework demonstrate that there are three typologies of digital strategy development approaches for manufacturing supply chains, namely: (i) top-down; (ii) bottom-up; and (iii) mixed. Every identified typology is supplemented with three determinant criteria for digital supply chain strategy formulation, i.e., number of suppliers, market demand, and product types. Noteworthy, the aforementioned strategies are context-dependent. This research contributes to the Operations Management field by formulating a novel strategy development framework for digital supply chains. The proposed framework, synthesised via strategic management theoretical views and primary evidence, can provide a reference point as companies chart their current and future digital supply chain strategy state.

Keywords: strategic management; supply chain management; digital supply chain strategy typologies; supply chain digitalisation criteria; digital strategy development.

Managerial Implications

Digitalisation has brought upon the rapid proliferation of changes that require instant decision making across end-to-end supply chains. Thus, for an organisation to remain competitive, effective processes are

essential to eliminate unnecessary time delays and material/energy/financial/information losses. The speed at which managers are expected to respond to the dynamically changing market conditions is overwhelming. In this regard, digital transformation claims are promising; however, evidence has shown that significant challenges associate with the integration of digital technologies into existing supply chain operations. Therefore, this research provides a structured approach for managers to develop digital supply chain strategies. The proposed novel framework in this research allows managers to understand the mechanics behind the development of digital strategies. In addition, this study identifies determinant criteria that differentiate the digital supply chain typology to be adopted. This structured approach provides clarity for practitioners in adopting digital supply chain strategies, thus allowing effective development and growth to achieve desired operational outcomes and competitiveness.

I. INTRODUCTION

The manufacturing industry is facing significant transformations with the emergence of digital technologies during the recent decades. In order to maintain competitive edges, organisations try to adapt rapidly to digitalisation through the transformation of operations and processes [1]. This digital transformation has been collectively addressed in the extant scientific and business literature as what is more commonly known as Industry 4.0 [2]–[4]. Industry 4.0 has embedded itself in multiple facets of business operations such as 3D printing in manufacturing, big data analytics in operations, and cloud computing for improved integration of manufacturing resources [5]–[7]. The importance of digital technologies has accelerated significantly with the Covid-19 pandemic, where technologies are utilised to navigate through the plethora of risks and disruptions across end-to-end supply chains; at the same time, firms rethink their global supply chain network [8], [9]. For example, the application of big data analytics in operations enables organisations to harness value from an extensive array of data for informed decision making and improved operational results [5], [10]. Industry reports by Mckinsey & Company [11] and OECD [12] demonstrated the potential of digital transformation to increase performance in multiple supply chain operations by at least 5-10%, such as in sales, transportation, and inventory

management. This need for operational excellence signals the dawn of a new era necessitating traditional supply chains to adopt the digitalisation paradigm by integrating pertinent technologies into the diverse types of operations across supply chain networks [13]. Companies have responded swiftly to this need through significant investments to attain associated benefits and achieve competitive advantages, including operations integration, transparency, and productivity [14]. A recent market report projects that by 2022 the global investments in technologies and services enabling digital transformation will reach about US\$1.97 trillion at a five-year compound growth rate of 16.7% [15], [16].

Notwithstanding the prospects of digitalisation of business processes, studies have shown that only 7% of companies entirely harness the benefits of such technology transformation [17]. Several studies have identified tactical and operational challenges in the digitalisation of traditional value chains, such as the lack of a skilled workforce and the limited availability of financial resources [18]–[20]. Despite the few empirical studies on the barriers of digitalisation, a more integrated view is required so that companies can reflect upon individual operations and system-level challenges to envision the necessary digital interventions [21], [22]. Therefore, a major gap towards the digitalisation of business processes can be attributed to the lack of understanding about how manufacturing firms can develop digital strategies for integrating and deploying digital technologies in operations [23], [24]. This gap is further amplified by the fact that companies have established business strategies such as lean, agile and leagile [18], [19], [21], which are characterised by dominant structural elements that render digital transformation even more challenging. In this regard, the greatest peril in the digitalisation of existing manufacturing operations refers to the lack of strategies that could inform and catalyse such transformation [22], [23], [25], [26].

The digitalisation movement unveils new possibilities for supply chains to explore novel adaptability strategies in terms of redesigning material and information flows for improved operational efficiency and responsiveness, such as in the cases of Lego and Netflix [9]. However, according to Büyüközkan and Göçer [27], a limited number of academic studies that focus on digitalisation strategies exists. In this regard, the aim of this research is to propose a framework for digital supply chain strategy development. Therefore, this study addresses the following overarching Research Questions (RQs):

- RQ1 – How are digital strategies developed in manufacturing supply chains?
- RQ2 – How do organisational characteristics and supply chain criteria impact the development of digital strategies?

This research contributes to the Operations Management field by formulating a novel strategy development framework for digital supply chains. Specifically, three distinct typologies for supply chain strategy formulation are identified. Firms can use any of these digital formulation strategies; however, each of these typologies is appropriate for certain types of context.

The remainder of the paper is structured as follows. Section II provides a literature review on supply chain digitalisation and management strategies, further reviewing the strategy formulation research field. Based on the literature review findings, Section III synthesises a digital supply chain strategy development framework that was used to conduct this research. Section IV further details the research methods employed, while Section V summarises the obtained results. Section VI presents the determinant criteria for digital supply chain development strategies. The final process framework that can inform the development of digital strategies in supply chains is described in Section VII. Contributions, limitations and future research opportunities are inserted in the final Section VIII.

II. LITERATURE REVIEW

A. An Understanding of Digital Supply Chains

In order to achieve a coherent conceptual structure of a topic in the management domain, a synthesis of evidence retrieved from the extant literature is necessary [28]. To this end, an initial generic literature search about the term “strategic management” in the Scopus database led to 2,000 results. The retrieved articles were analysed explicitly through a bespoke text-mining algorithm in the Python programming language to identify prominent authors and themes in the field of strategic management. Thereafter, to address the research queries, we supplemented the initial search results with additional relevant terms such as (“digital” OR “manufacturing” OR “supply chain strategy”) and the retrieved articles were then screened in terms of title and abstract to identify common keywords. These common keywords were then used to formulate the following search query to the Scopus and Web of Science databases and obtain

relevant peer-reviewed scientific articles: [(“strategy” AND “digital*”) OR (“digital supply chain*” AND “indust*”) OR (“supply chain strategy” AND “digital*”) OR (“strategy” AND “manufactur*” AND “digital*” AND “supply chain”)]. This search query led to more than 50,000 results. The literature search was limited to journal contributions written in English. We adopted the literature review methodology developed by Randolph [29] and selected a total of 794 citations based on title and abstract screening. The specific databases’ selection (i.e., Scopus and Web of Science) is attributed to the fact that these capture a broad range of peer-reviewed academic journals in the fields of Natural Sciences and Engineering [30]. Through content screening, we ultimately reviewed a total of 197 studies by the end of September 2021.

A bibliometric analysis of the reviewed articles, performed via the VosViewer software (<https://www.vosviewer.com>), demonstrated that digital supply chains have been studied from multiple perspectives, including “technology”, “efficiency”, and “cost”. However, the “framework” aspect is peripheral, as it has appeared in the pertinent literature only since 2020. Concurrently, “strategy” is still not a mature theme in the research domain of supply chain management (**Fig. 1**).

[Please insert ho1 here: Network map illustrating the relations between key terms in the field of digital supply chains (generated by VOSviewer 1.6.16 software).

The bibliometric analysis output and literature observations demonstrate that digital supply chains constitute an emerging research topic. Furthermore, recent studies indicate the intimate relation between digital supply chains and the data sharing concept through the utilisation of blockchain [31]–[33]. Noteworthy, a digital supply chain is defined as: *“intelligent, customer centric, system integrated, globally connected and data-driven mechanism that leverages new technologies to deliver valuable products and services that are more accessible and affordable”* [1], [34]. Büyüközkan and Göçer [27] presented a digital supply chain framework, but its applicability and suitability to industries were not exemplified. There is also a lack of integration between digital strategies’ implementation and supply chain characteristics [35]. To the best of our knowledge, only the literature studies of Hofmann [36] and Martínez-Olvera and Mora-Vargas [37] have demonstrated a linkage between these domains, but in a

rather vague manner. In particular, Hofmann [36] provided an interlink between supply chain strategy and strategic management, though overlooking the linkage to digital technologies. Martínez-Olvera and Mora-Vargas [37] explored digitalisation and supply chains, but their study was not focused on the integration of theoretical strategy development [38]. While Ahmed Khan et al. [1] focused on the critical factors of digital supply chains, their study lacks the corresponding development aspect for varied organizations. In addition, literature encompassing digital technologies mainly focuses on algorithms and individual deployment technicalities but lacks a holistic approach for strategy development [24], [39]. Stank, Scott and Hazen [40] provided a detailed review of use cases for a few digital technologies but did not provide the necessary insights required for managers to utilise digital technologies for decision making and in digital strategy deployment. Stank, Scot and Hazen [40] also highlighted the lack of structured approaches towards digitalisation in companies.

As supply chains are a differentiator among organisations, a rich body of literature surmounts this theme. However, when examined, it can be observed that extant literature mainly focuses on digital technologies as an enabler for companies to achieve desired performance. In this regard, through investigating the literature, we segregated digital technologies in manufacturing supply chains in two main categories: (i) information flow; and (ii) material flow, as there is a lack of structural approach to this domain (**Fig. 2**). This classification of technologies provides a basis and a structure for identifying the most common technologies considered in the design and development of digital supply chains. Specifically, in digital manufacturing networks, information flow shall be enabled by real-time data analytics to support decision making for improved scheduling and planning of operations with further implications in both upstream and downstream echelons such as visibility, resilience, product safety and consumer trust [35]. Additionally, material flows supported by robotics and automation can enable real-time data gathering whilst optimising processes and improving operational performance (e.g., production throughput, lead time) for better positioning in the competitive manufacturing landscape [41].

[Please insert ho2 here: Segregation of digital technologies for manufacturing supply chains.]

Information flow technologies mainly focus on real-time data analytics across a supply chain. Such technologies focus on capturing, analysing and generating insights from data [23], [29], [42]. Digital technologies in this category include artificial intelligence, Internet of Things (IoT), cloud computing, big data analytics and wearables. Bluetooth, sensors, and RFID technologies can be categorised in one group, namely Real-Time Location Sensing (RTLS), as these provide the ability to track information flows across supply chains through real-time data analytics [13], [27]. Tangible results are observed through Wal-Mart's and Proctor & Gambles's inventory reduction by 70% enabled by the application of IoT [43]. To a greater extent, wearable technologies integrate augmented and virtual reality applications. For example, Microsoft Hololens, a pair of mixed reality smart glasses, is used for employee training in hazardous environments [44].

In addition, the primary function of material flow technologies is to improve efficiency and effectiveness in repetitive tasks or manual activities [40]. Applications like robotics, automated guided vehicles and 3D printing reside within material flow technologies [45], [46]. Robotics and, in particular, collaborative robots are recognised to have a catalytic role in the efficiency improvement of repetitive tasks such as packaging activities in a manufacturing line. The use case for robotics was even more dominant during the onset of the Covid-19 pandemic, where there was a critical need for massive organisational changes [47]. Although there is a rich body of literature focusing on digital technologies in supply chain operations, a lack of a structured approach towards digitalisation among companies is evident [40]. Thus, a supply chain strategy framework needs to be investigated to identify strategy formulation approaches for digitalisation. A proper strategy for the digital transformation of supply chains is necessary to overcome the related challenges and facilitate information sharing and informed decision making across end-to-end echelons of operations [48].

B. Supply Chain Strategies

The investigation of the extant literature that was conducted within the purposes of this research revealed three key supply chain strategies, namely: (i) 'lean'; (ii) 'agile'; and (iii) 'leagile'. First, the idea of 'lean' supply chains was proposed by Womack and Jones [49], who expanded the concept of Taiichi Ohno, the

creator of the Toyota Production System. Case study results indicated that the integration of this strategy across the organisation was lacking [49]. This strategy focuses on eliminating waste, also known as ‘muda’¹ from the customer’s perspective. It is recommended that this is applied across each product’s value stream encompassing three critical business activities: product definition, information management, and physical transformation. From the supply side, it is recommended to adopt a pull approach where customers pull products from the value stream and thus reduce waste stemming from high inventories. This just-in-time strategy implies a zero inventory which most ‘lean’ manufacturing companies fail to achieve in upstream operations [50]. It is thus highlighted that this strategy is applicable in the domain where market demand is relatively stable and predictable. In more volatile markets, downstream agility may be unsuitable to meet customer demand, and thus an ‘agile’ supply chain strategy would be better suited.

Second, an ‘agile’ supply chain can be defined as a “*business-wide capability that embraces organisational structures, information systems, logistics processes and in particular mindsets*” or “*the ability of an organisation to respond rapidly to changes in demand, both in terms of volume and variety*” [50], [51]. This strategy is rooted in Flexible Manufacturing Systems (FMS) and focuses on utilising automation to enable rapid changeovers and meet varying product mix demands [52]. ‘Agile’ supply chain strategies focus on the response to actual demand, while ‘lean’ strategies focus more on optimising performance to attain a better competitive position, such as through optimised inventories and just-in-time approaches [50], [53]. An example is the Efficient Consumer Response (ECR) and the utilisation of information technology to capture real-time demand signals, thus creating a virtual supply chain² [9]. To a greater extent, ‘agile’ strategies view supply chains as a network; a key agility element is attributed to the fact that businesses do not compete individually but rather as an integrated supply network. Through

¹ ‘Muda’ is the Japanese term for waste.

² A virtual supply chain refers to a supply chain that is information-based rather than inventory-based.

this consideration, the need for integration extends beyond the boundaries of a firm to its suppliers and necessary alliance partners. Supply chain criteria for these strategic views are summarised in **Table I**.

Table I. Key criteria of ‘lean’ and ‘agile’ supply chain strategies.

Criteria	‘Lean’ Supply Chain Strategy	‘Agile’ Supply Chain Strategy
<i>Number of Suppliers</i>	Low	High for increased flexibility
<i>Lead Time Compression</i>	Reduction of lead times	Respond to market demand
<i>Elimination of Waste</i>	Essential	Desirable
<i>Rapid Configuration</i>	Desirable rapid configuration through shorter changeover times	Essential to respond to the changing market requirements
<i>Robustness</i>	Not viewed as critical	Essential to withstand disturbances
<i>Market Demand</i>	Predictable	Volatile
<i>Focus</i>	Cost-driven	Responsiveness to customer demand
<i>Product Variety</i>	Low product variety	High product variety to meet demand
<i>Products Types</i>	Standard	Specialised
<i>Product Lifecycle</i>	Long product lifecycle as demand is relatively stable	Short product lifecycle with changing market demand
<i>Number of Customers</i>	Low	High
<i>Customer Drivers</i>	Cost	Lead time and availability
<i>Profit Margin</i>	Low	High
<i>Dominant Costs</i>	Physical costs	Marketing costs
<i>Stockout Penalties</i>	Tied to stable market demand and to ease of planning	Immediate and volatile
<i>Market Winner</i>	Cost	Availability to address market demand
<i>Main Driver</i>	Cost	Responsiveness

Source: [53]–[58].

Third, the ‘leagile’ supply chain strategy was introduced by Naylor, Naim and Berry [55], who combined ‘lean’ and ‘agile’ elements. As the latter were often considered in isolation or sequence, the study proposed that these strategy views are rather simplistic and should be combined successfully at the decoupling point. The decoupling point is defined as: “... *part of the organisation [supply chain] oriented towards customer orders from the part of the organisation [supply chain] based on planning*” [50], [53], [55]. It is seen as the point of differentiation when considering either ‘lean’ or ‘agile’ strategy adoption towards the end-user or the supplier side. This is also tied to postponement, which increases the point of differentiation towards the end-user and reduces the pressure of high inventories [55]. Characteristics

incorporating both views are referred to as ‘leagile’ supply chains. The ‘leagile’ strategy proposes an optimal combination of upstream ‘lean’ supply chain processes followed by an ‘agile’ approach downstream at the decoupling point [53].

Notwithstanding the extant body of research on Operations Management, the relevant literature on digital supply chain strategy formulation is limited. Existing studies mainly focus on the description of strategies but lack inputs on developing digital supply chains. Therefore, we turn our attention to the core of strategy development, i.e., the strategic management research area.

C. Strategic Management Perspectives on Strategy Formulation

As this research aims to provide a structural approach for managers to develop digital supply chain strategies, it is necessary to understand and synthesise relevant theoretical underpinnings. Therefore, from a theoretical viewpoint, we reviewed the “Resource-based View”, the “Industry-based View”, the “Dynamics Capabilities” theory and the “Institution-based View” for systematically investigating supply chain strategies for digitalisation. A combination of these theories was applied to propose a strategy development framework for digital supply chains. In particular:

1) “Resource-based View”

Penrose’s seminal work on resource-based view directed the strategy development focus to the firm [59]. Here, the firm is defined as: “... a collection of (productive) physical and human resources” [59]. The combination of such resources can provide certain types of competence capability. The study of a firm’s resources, capabilities, and competence provides a unique framework for firm-level strategies [60]. In this view, resources are not assumed to be homogenous [61]. A key limitation of this consideration is that it overlooks the role of a firm’s political and business environment in developing strategies. “Resource-based View” provides a unique opportunity for digital transformation strategy development; however, it is not clear how heterogeneous resources of a firm are identified and evaluated for strategy development.

2) *“Industry-based View”*

Early “Industry-based View” emerged from the academic work of Bain [62] and Mason [63], who looked at the relationships between the industry and firms in strategy development. Subsequently, the “Porter’s Five Forces” framework helps firms develop competitive advantage strategies based on the analysis of firms’ position within an industry [64]. The framework by Porter further strengthens the relationship between an industry and a firm within the context of strategy formulation. This relationship is mature and is well apprehended as the “Industry-based View” highlights the five industry-level forces, i.e., entry barriers, threats of substitution, bargaining power of buyers, bargaining power of suppliers, and rivalry among industry incumbents [64], [65]. There are two major assumptions, namely: (i) resources are considered homogenous; and (ii) strategies are developed by primarily focusing on a firm’s position within an industry [65]. However, applying the “Industry-based View” for digital strategy formulation is not well understood, especially in the way industry structure and firms’ homogenous resources shape distinct digitalisation strategies.

3) *“Dynamic Capabilities”*

“Dynamic Capabilities” combine the latter internal and external views of strategic management. In particular, “Dynamic Capabilities” extend the “Resource-based View” through acknowledging the dynamic nature of resources to achieve new forms of competitive advantage [66]. This perspective focuses on renewing existing competencies and responding in an agile manner to a changing environment. “Dynamic Capabilities” build upon the notion of 5P’s strategy introduced by Mintzberg [67], where the strategy is viewed as: ‘Plan’, ‘Ploy’, ‘Pattern’, ‘Position’ and ‘Perspective’. ‘Plan’ refers to an intended course of action derived from senior management; ‘Ploy’ is a trick deployed to obtain a competitive edge incorporating the “Industry-based View” by Porter [64]; ‘Pattern’ is defined as a set of actions either tactical or strategic which is time-sensitive [67]; ‘Position’ is recognised as the mediating force merging from the external and internal context for a good fit; and ‘Perspective’ focuses on the

internal ingrained view of organisational cultures. Therefore, the “Dynamic Capabilities” theory suggests that strategy formulation is not a static concept denoting that strategy can change during the implementation phase. However, the changing nature of a strategy, especially in the digitalisation context, has not been observed and studied.

4) “*Institution-based View*”

The “Institution-based View” acts as a complementary view to further support the “Resource-based View” of the variance between firms by highlighting the balance of formal and informal influences of geographical regions. Additionally, it supplements the “Resource-based View” of differentiation through core capabilities by emphasising the importance to consider the formal and informal “rules of the game”. Furthermore, it extends the scope or strategy to consider factors beyond the firm. The “Institution-based View” focuses on the institution distance which exists between two geographical locations through the consideration of political, economic, legal, social, religious and cultural differences [68]. This approach to digital supply chains is lacking in the extant literature. There is an insufficient linkage between the effects of institutional distance and the development of digital strategy.

Overall, the key characteristics of the abovementioned theoretical lenses on strategy development are summarised in **Fig. 3**. In particular, the “Resource-based View” considers firm strategic resources and capabilities as assets that are valuable, rare, difficult to imitate, and non-substitutable, and which can be leveraged to enable an enduring competitive advantage [61]. A critical assumption of the “Resource-based View” is that resources are heterogeneous. Furthermore, the “Industry-based View” opines that the environmental conditions in an industry can influence the strategy of firms [64]. A critical consideration of the “Industry-based View” is the homogeneity of conditions in an industry. Additionally, “Dynamic Capabilities” acknowledge the aspects of plan, ploy, pattern, position, and perspective as critical strategic constituents to leverage and materialise firms’ strengths, competencies and capabilities [67]. Lastly, the “Institution-based View” recognises the influence of formal and informal institutional arrangements on international business strategy and performance [68].

[Please insert ho3 here: Strategy development theoretical lenses.]

Notably, the dominant theoretical views on strategic management can also be categorised as internally or externally focused. The “Resource-based View” has an internal emphasis on strategic management, while the “Industry-based View” adopts an external focus. “Dynamic Capabilities” combine the latter two perspectives by adopting a mixed viewpoint, while the “Institution-based View” addresses the larger ecosystem of strategy management.

III. SYNTHESIS OF A DIGITAL SUPPLY CHAIN STRATEGY DEVELOPMENT FRAMEWORK

We argue that digital supply chain strategy development should reflect upon existing and/or required resources and capabilities of the involved actors to: (i) effectively embrace digitalisation; (ii) address particularities and challenges of the operational environment; and (iii) achieve competitive advantage. In this regard, “Dynamic Capabilities” aspects shall transcend both the internal and external operations management environment. Especially in supply chain management, dynamic capabilities are documented to positively influence operational, technological and marketing competencies [69], thus leading to improved flexibility and cost-efficiency [70].

Regarding the internal environment, a supply chain digital transformation strategy has to be planned based on a rational analysis of the involved firms’ organisational layers, structure and control systems [71] to mobilise accordingly the available resources and capabilities. In addition, the perspective of a digital strategy typically reflects upon and is influenced by established organisational interpretative views [72] and experiences [73] about the management of internal resources and capabilities. Ultimately, the digitalisation effort has to be consistent, and the use of resources and capabilities shall respond to the changing environmental circumstances [71].

Concerning the external environment, the digitalisation of supply chain operations could be used as a manoeuvre to influence the competitive environment and its conditions [74]. In addition, a decision over the market positioning of a supply chain is critical to inform the appropriate digitalisation initiatives. In a similar vein to individual businesses [71], digital interventions may transform the supply chain operating

model and vice versa. Owing to the global scale of modern supply chain operations, the consideration of location parameters is vital to inform digital initiatives [68], e.g., regulatory approval of continuous manufacturing technologies for pharmaceuticals in different geographical regions.

A digital strategy framework was synthesised in this research by combining the pertinent strategic management views and identifying the respective gaps concerning digital strategy formulation (as described in Section II.C). In particular, the proposed framework merges internal aspects of the “Resource-based View” and external elements of the “Industry-based View” and “Institution-based View” so that organisations can leverage “Dynamics Capabilities” and structure their pathway towards digital strategy development. This structural approach aims to provide a basis to explain how organisations can develop a digital strategy framework. The framework consists of both internal aspects, i.e., ‘Plan’ (PN), ‘Pattern’ (PA) and ‘Perspective’ (PE), and external facets denoted by ‘Ploy’ (PY), ‘Position’ (PO) and ‘Place’ (PL). Therefore, the consideration of the four underpinning theoretical views helps to formulate a digital supply chain strategy development framework (**Fig. 4**) since their synthesis covers all relevant strategic aspects in Operations Management.

[Please insert ho4 here: Digital supply chain strategy development framework.]

Notwithstanding the plethora of studies on the content of strategy, a process-oriented view concerning strategy formulation needs to be contemporarily considered; such consideration will help catalyse the operationalisation of internal and external facets and achieve coherent objectives, particularly in operations-intensive sectors such as manufacturing [75]. In this regard, the work of Skinner [76] conceptualised the process of operations strategy formulation as a top-down process, with Wheel Wright [77] supporting this notion for the development of organisational structure, infrastructure, and capabilities for competitiveness. A different school of thought advocates a bottom-up process model of operations strategy formulation to leverage shop floor tacit knowledge [78]. More recently, the integration of top-down and bottom-up action plans was considered whilst unveiling their complementary roles in operations strategy formulation [79].

IV. METHODOLOGY

This research is grounded on a combination of a deductive literature review and an inductive interpretation of in-depth case studies (**Fig. 5**). Firstly, we carried out a comprehensive literature review to identify the key domains in digital supply chains. We used Scopus and Web of Science databases to obtain relevant literature based on the research methodology developed by Randolph [29] and Pilbeam [80]. The findings revealed that the research topic of digital supply chains is nascent, only emerging during the last years (i.e., 2018-2021). The extant literature also demonstrated a lack of holistic approaches towards the development of digital supply chain strategies. In particular, extant studies focus more on the digital aspects of operations rather than on strategic management considerations of digital supply chains.

Owing to the nascent nature of the topic, a case study methodology was selected as it is most suitable to address this emerging area of research [81]. Barnes [78] stated that: “... *the most appropriate methodology for those who seek to answer the call for more empirical research on the operations strategy process is that of the case study*”, thus further supporting the validity of our methodological view in this research. Based on the theoretical underpinnings, a conceptual framework was designed by combining three distinct research areas, namely: (i) digital supply chains; (ii) supply chain strategy; and (iii) strategy development. This conceptual framework was then used as a guide for the development of a semi-structured questionnaire; the framework also served as a basis to codify the gathered interview data and identify key patterns within- and cross-case analyses. In order to analyse the case studies, we applied the theoretical proposition approach followed by an analytical within- and cross-case analysis of pattern matching, explanation building and logic model [82]. Thematic coding was carried out via using the qualitative data analysis software Maxqda (<https://www.maxqda.com>). Ultimately, we applied theoretical approaches and analytical methods to analyse the gathered primary data [83].

[Please insert ho5 here: Methodology flowchart.]

The proposed digital supply chain strategy development framework was applied to twelve multinational companies. Due to the status of ongoing digitalisation projects, the approached companies requested to be anonymised. Therefore, these were labelled as Company A to L instead. Representative industrial

experts were interviewed to understand the development process of digital strategies in each company. Specifically, primary data was obtained through semi-structured interviews conducted with twenty industry experts. The engaged organisations were retrieved from the Forbes Global 2000 list, while the experts that were engaged have experience in the digital transformation of their organisations (**Table II**). The interviewed industry experts represent companies from six diversified sectors, namely: (i) Aerospace; (ii) Oil and Gas; (iii) FMCG; (iv) Industrial Air and Gas; (v) Business and Services; and (vi) Pharmaceuticals. The range of sectors was selected to provide a holistic understanding of digitalisation strategies in manufacturing.

Each company was studied based on the implemented digital technology(ies). The applied digital technologies vary across companies (even within the same sector) and involve a range of applications facilitating material and information flows (**Table II**). Specifically, the observed information flow technologies include: Artificial Intelligence, Big Data Analytics, Cloud Computing, Functional Business Systems, and IoT. In terms of material flow technologies, these include Bluetooth, RFID, Automated Guided Vehicles, robotics, and drones.

Table II. Interviewed industrial experts, representative sectors and implemented digital technologies.

Company / Case	Informant / Respondent	Sector	Position	Experience (years)	Digital Technologies
A	R1	Oil and Gas	Senior digital lead	7	AI; BD; Drones
	R2		Senior project manager	8	
B	R3		IT analyst	8	Applications; BD; CC
	R4		IT project lead	10	
C	R5		Project lead	10	
	R6		Subsea engineer	4	
D	R7	Chemicals	Digital project lead	3	Applications; BD; CC; FBS; IoT
	R8		Digital analyst	5	
E	R9	Pharmaceuticals	Site digital lead	19	AGVs; AI; Applications; FBS;

Company / Case	Informant / Respondent	Sector	Position	Experience (years)	Digital Technologies
	R10		Digital project lead	5	Robotics; Wearables
F	R11	Aerospace	Procurement	> 20	Bluetooth; FBS; IoT
G	R12		Continuous improvement	7	CC; FBS; IoT; RFID
H	R13	FMCG	Technical manager	9	CC; IoT; RFID
I	R14		Global lead manufacturing	10	Applications; Bluetooth; CC; IoT; Robotics
	R15		Plant director	15	
J	R16		Regional supply chain manager	10	Applications; CC; FBS; IoT; RFID; Robotics
K	R17	Business and Services	Project lead engineer	10	Applications; CC; FBS; IoT; RFID; Robotics
	R18		Customer service	16	
L	R19	FMCG	Strategic project lead	23	IoT; Robotics
	R20		Manufacturing analyst	7	

Symbol: AI – Artificial Intelligence; BDA – Big Data Analytics; CC – Cloud Computing; FBS – Functional Business Systems; IoT – Internet of Things; AGVs – Automated Guided Vehicles; RFID – Radio-Frequency Identification.

Generally, the two major disadvantages of a case study research approach are, as highlighted by Yin [82], “*response bias*” and “*inaccuracies due to poor recall*”. To this end, reliability and validity checks are required. Therefore, in this study, we applied a series of tests to mitigate the aforementioned challenges related to the nature of our research. First, the “*response bias*” was addressed by triangulating the gathered data from multiple sources (i.e., interviews, companies’ background information, secondary data). Second, any “*inaccuracies due to poor recall*” were addressed through the voice and video recording of the interviews (after receiving the consent of the involved informants). A transcription was then carried out to ensure that the information was extracted without loss of data. Furthermore, secondary data and corporate documentation were also used to complement the primary data to ensure quality and comprehensiveness. The steps that were undertaken to ensure construct validity, internal validity, external validity and reliability are summarised in **Table III**.

Table III. Data gathering reliability and rigour tests.

Test	Case Study Tactic	Application to Research
Construct Validity	<ul style="list-style-type: none"> ▪ Use of multiple sources of evidence. ▪ Establish a chain of evidence. ▪ Have key informants to review draft case study reports. 	<ul style="list-style-type: none"> ▪ Use primary and secondary data. ▪ Leverage the research questions, which determine the research strategy and design variables for the study. ▪ Transcribe data and circulate it to the respondents for validation.
Internal Validity	<ul style="list-style-type: none"> ▪ Use pattern matching or explanation building, or time-series analysis. 	<ul style="list-style-type: none"> ▪ Codify the data, i.e., open, axial and selective coding.
External Validity	<ul style="list-style-type: none"> ▪ Use replication logic in multiple case studies. 	<ul style="list-style-type: none"> ▪ Use the coded variables across multiple cases.
Reliability	<ul style="list-style-type: none"> ▪ Use a case study protocol. ▪ Develop a case study database. 	<ul style="list-style-type: none"> ▪ Use a case study protocol. ▪ Leverage literature review evidence, conceptual frameworks and semi-structured questionnaires.

V. RESULTS

In alignment with Kim, Sting and Loch [79], this research recognises that the formulation of supply chain strategies shall: (i) integrate internal and external facets of an organisational environment; (ii) include top-down planning to reflect upon top management’s strategic intentions; and (iii) induce bottom-up learning for leveraging practices and processes at an operational level. Ultimately, a mixed action plan complementarily integrating top-down and bottom-up processes can stimulate niche research areas in the strategy development domain. In this context, the analysis of the secondary evidence revealed three distinct digital strategy development typologies for supply chains, along with a process framework, namely: (i) top-down; (ii) bottom-up; and (iii) mixed (**Table A.I** and **Table A.II** in the Annex).

Top-down Digital Supply Chain Strategy: The Project Lead in Company A stated that a digital strategy formulation was initiated, from a business perspective, by the top management to build the required digital culture. To a greater extent, the Project Lead from Company C discussed how the various fixed projects were mapped out to build digital capabilities in the organisation. The Project Lead from Company D described digital strategies as “*top management’s aim to establish smart innovation hub*”. A consideration of ‘Place’ is evident through statements such as “*given the expertise in this country*” (Company B), “*the infrastructure is different from Europe*” (Company C), “*it depends on the site itself*” (Company D). Thus,

companies adopting this strategy development process demonstrate a clear and structured senior management plan while considering strategic locations and resources as vital in the formulation of digital strategies, hence integrating the localisation aspect of strategy development. In addition, it was observed that companies adopting this digital strategy development typology have a lower number of suppliers with standard product types, thus resulting in a lower degree of supply chain flexibility. This situation calls for a top-down process view to ensure consistency across the supply chain and embrace digitalisation (**Fig. 6**). Moreover, the markets in which Companies A to D operate are highly volatile, thus indicating the need for structure to respond to the dynamic nature of these sectors.

[Please insert ho6 here: Top-down digital supply chain strategy development typology.]

The top-down typology involves the development of strategy from the senior leadership team through a structured and deliberate plan for the company. Furthermore, the top-down approach displays that the process of digital strategy development starts from a senior management decision (denoted by ‘Plan’), combined with external considerations (represented by ‘Place’), to nurture a concerted digital culture in the company (defined by ‘Perspective’).

Bottom-up Digital Supply Chain Strategy: This strategic development process is more flexible and adaptive, as demonstrated by Companies F to I. The Procurement Lead in Company I described their approach as: “*we are not building a central digitalisation strategy, but rather we are seeking the consultancy of each factory as they know the optimisation potential*”. He further added that it is dependent on various business units through a decentralised approach. Companies G and H described it as primarily an ideation and proposal via a digital lens. Companies adopting this flexible approach are understood to adopt a decentralised approach to the development of digital strategies as they have a digital culture that has been infused across the company. This is apparent through statements such as: “*it [digital] is seen as an enabler and influences the overall strategy*” (Company F), “*desired outputs were proposed by the various users*” (Company H), “*... we launch digital initiatives and request an IT team for additional help (if necessary)*” (Company G), and “*... dependent on various use cases raised by the functions*” (Company I). Companies F to I utilised sourcing from many Tier 1 suppliers hence indicating a more flexible

sourcing strategy. This is coupled with a wider variety of product types. Stemming from the aerospace and FMCG sectors, they both demonstrated predictable market demand. Therefore, due to the higher flexibility and complexity involved, it is seen that a bottom-up typology is more suited for digital strategy development as it is able to address the needs of the various business units within a company. A lower market demand volatility also deems this approach more suitable because it enables companies to capitalise on the organisational digital culture and develop their digital strategies through a decentralised manner across the various business units in a company, as opposed to the top-down process view. Therefore, the bottom-up approach is understood as the process of movement of the combination of three starting points, i.e., 'Place', 'Pattern' and 'Perspective', towards the final formulation of a digital strategy plan approved by senior management, as denoted by the 'Plan' aspect (Fig. 7). This approach can be interpreted as a concerted effort from the various business units across the different levels of the focal organisation to formulate a digital supply chain strategy.

[Please insert ho7 here: Bottom-up digital supply chain strategy development typology.]

Mixed Digital Supply Chain Strategy: Company E uniquely focused on combining knowledge from both the senior management and individual digital teams (e.g., via hackathons). It started from the views of the senior management where according to the Project Engineer: "... *it was mainly from the senior management who saw the potential in digitalisation*". The Digital Lead from Company E also added that many individual teams came forward with ideas for realising the digitalisation potential: "... *it was surprising to see people from different departments coming to me with ideas and initiatives*". Therefore, this approach is the combination of structured senior management direction (i.e., 'Plan') with initiatives from the other levels of an organisation (i.e., 'Perspective') hence resulting in repeated actions that can lead to the development of digital strategies (i.e., 'Pattern'). This concerted approach, deriving from both centralised and decentralised engagements, resulted in a mixed typology for digital strategy formulation

(Fig. 8). Company E also demonstrated a lower number of suppliers, standard product types and more predictable market demand.

[Please insert ho8 here: Mixed digital supply chain strategy development typology.]

VI. DETERMINANT CRITERIA FOR DIGITAL SUPPLY CHAIN DEVELOPMENT STRATEGIES

This research revealed that a unique digital supply chain strategy development approach does not exist. On the contrary, evidence demonstrates three typologies to digital supply chain strategy development, as already identified, namely: top-down, bottom-up, and mixed. At a more granular level, compliance to specific criteria could influence the process of formulating an operational strategy [79]. **Table I** identifies a range of criteria for ‘lean’ and ‘agile’ supply chain strategies. Amongst these, further analysis of the gathered primary data unveiled the existence of three common determinant criteria that can affect the development of each identified digital supply chain strategy typology, namely: (i) number of suppliers; (ii) market demand; and (iii) product types.

First, upstream a supply chain, a higher number of (Tier 1) suppliers results in a more decentralised bottom-up approach. Companies F, G, H and I adopt a decentralised strategy formulation approach. In contrast, Companies A, B, C and D have fewer suppliers and thus fall into a more centralised system.

Second, in terms of products, companies with standard product types are seen to adopt a more top-down approach compared to companies with specialised product types. Companies A, B, C and D produce a standard product type, enabling a top-down approach for digital strategy development in response to the homogenous nature of products in the industry. On the other hand, the bottom-up digital strategy development is applied to organisations with standard and specialised products. This is attributed to the variation of strategic undertakings for each product type, thus giving rise to a more bottom-up approach.

Third, market demand has an influential role in the strategy typology. It is observed that in markets with volatile demand, a centralised top-down approach is suited. Specifically, a top-down strategy provides a better structure to navigate through potential uncertainties in demand, as seen in Companies A, B, C and

D. In more predictable markets, both bottom-up and mixed strategy typologies are seen to be adopted by companies.

The findings of this research provide an extension to the study carried out by Kim, Sting and Loch [79] through the incorporation of the digital strategy aspect. The effect of supply chain criteria on developing a digital strategy is a relatively new concept and provides stimulating research grounds as it merges the strategic management domain with the more focused operational-level characteristics of a supply chain. The identification of the determinant role of these three criteria was unexpected due to the complexity involved in the strategy development domain. However, these would prove useful for future studies and managerial understanding of the strategy development process.

Moreover, apart from the determinant criteria relating to supply chain characteristics, a company's profile also contributes to the formulation of a digital supply chain strategy. Companies with more exposure to digitalisation demonstrate a more decentralised bottom-up approach (Companies F, G, H and I). This could be attributed to the digital culture which is cultivated in the various business units, thus resulting in a more independent approach in the formulation of digital strategies. In contrast, companies with less engagement in digitalisation tend to adopt a centralised approach resulting in either a top-down or mixed approach for digital strategy formulation. **Table IV** summarises the key observed company characteristics and influential criteria of digital supply chain strategies.

Table IV. Determinant company characteristics and criteria for digital supply chain strategy development.

		Digital Supply Chain Strategy Development Typology		
		Top-down	Bottom-up	Mixed
Company Characteristics	▪ Revenue/Size (£)	Medium (more than £10 billion) to high (more than £100 billion)	Medium range (>£10 billion)	Medium range (>£10 billion)
	▪ Digital Strategy Adoption (years)	Mainly adopted digital supply chain strategy for a medium-term (3-4 years)	Digital supply chain strategy has been adopted for more than 4 years	Relatively new to digital supply chain strategy (less than 2 years)

Criteria	▪ Number of (Tier 1) Suppliers	Low	High	Low
	▪ Product Type	Standard products	Standard and specialised products	Standard products
	▪ Market Demand	Volatile	Predictable	Predictable

VII. PROCESS FRAMEWORK FOR DIGITAL SUPPLY CHAIN STRATEGY DEVELOPMENT

This research combines evidence acquired from the surveyed companies with the aim to chart a process framework for the development of digital supply chain strategies. The framework includes three main phases: (i) strategy development; (ii) strategy implementation; and (iii) strategy evaluation (**Fig. 9**). In the first phase of strategy development (Phase 1: Strategy Development), a company's vision and characteristics should be clearly identified. Then, the internal and external characteristics impacting the company should be listed to understand the residing ecosystem. Afterwards, both internal and external VRIN³ resources have to be determined.

The second phase (Phase 2: Strategy Implementation) requires an assessment of the suitability of the current supply chain. The current state is then compared with the future strategic direction of the company. Through this comparison, gaps that suffice should be detailed. At that point, through workshops or brainstorming sessions with cross-functional groups, focus areas should be developed to address the current gaps and fulfil the company's vision. Through the identification of these focus areas, digital technologies best suited for the deployment are then selected. This selection focuses on the improvement of either material or information flows within the supply chain.

From the selection of digital technologies in Phase 1, companies can then proceed to the implementation of digital strategies in Phase 2, which is followed by the evaluation of the effectiveness of the technologies

³ Valuable, Rare, Inimitable, Non-substitutable.

in the third phase (Phase 3: Strategy Evaluation). The two latter phases provide stimulating research grounds and will be explored in future studies to identify relevant key components.

[Please insert ho9 here: Process framework for digital supply chain strategy development.]

VIII. CONCLUSIONS

The advent of digitalisation necessitates pertinent supply chain strategies to harness competitive advantages. To this end, this research synthesises primary and secondary evidence, and concludes that there is not a one-size-fits-all approach for the development of digital supply chain strategies in the manufacturing landscape. Specifically, through the engagement with multinational organisations, this research developed a novel framework that identifies three main digital supply chain strategy typologies, namely: (i) top-down; (ii) bottom-up; and (iii) mixed. The analysis in this research further recognises three influencing organisational design criteria, that is: (i) number of suppliers; (ii) market demand; and (iii) product types.

This research extends the current literature on strategic management by introducing a novel hexagonal strategy development framework. The extant literature on digitalisation of supply chains is fragmented, thus leading to diverse understandings in academia. The provided framework synthesises various strategic management views as elaborated earlier by prominent authors such as Porter [65] (“Industry-based View”), Penrose [59], Wernerfelt [84] and Barney [61] (“Resource-based View”), Peng [85] (“Institution-based View”), and Mintzberg [86] (“Dynamic Capabilities”). Through incorporating these latter theoretical perspectives, we introduce an alternative dynamic view on strategy development, in contrast to Porter’s static view of strategy characteristics.

The proposed novel framework in this research merges the various strategic management theories and applies them to primary case studies. Furthermore, the case studies’ contribution is encapsulated in the fact that these provide practical relevance to the framework and further enhance its reliability. Therefore, the academic contributions of the proposed framework can be summarised in the following:

1. It provides the necessary understanding of the domain, as raised by Hofmann and Rüsçh [45].

2. It has practical applicability, in contrast to the theoretical framework by Büyüközkan and Göçer [27].
3. It provides the digitalisation aspect to the study of Hofmann [36].
4. It addresses the missing link of strategy development in the study conducted by Martínez-Olvera and Mora-Vargas [37].

Moreover, this research also extends the work of Kim, Sting and Loch [79] through the adoption of a different lens and application to digital strategies. Our case studies also encompass a more heterogeneous selection of organisations to overcome the homogeneity limitation mentioned by Kim, Sting and Loch [79]. To wrap up, through merging three key domains, i.e., strategic management, supply chain, and digitalisation, this research addresses the missing link between these identified fields in the extant literature.

Despite the advent of Industry 4.0, existing studies mainly focus on the application side of digital technologies. This observation stems from the analysis of both the literature and primary case studies [40]. Through our interviews, we realised that organisations are mainly approaching digitalisation by using various development styles, without linking it to strategic management theories or considerations of supply chain organisational designs. Thus, through our research, we connect the various success stories of digital strategies across multinational companies and provide a blueprint for other organisations to chart their future path of digitalisation.

The novel framework introduced in this research can provide a point of reference as companies chart their current and future state of digital supply chain strategy. As a supplement to the framework, companies could also explore simulation-based modelling to optimise processes [87]. Digital tools such as testbeds could also be leveraged to provide the necessary validated solutions to ensure smooth operations [88]. This aids in better decision making for practitioners and provides the much-needed structure in adopting digitalisation, as highlighted by Stank, Scott and Hazen [40]. Our research also reveals the commonalities in terms of challenges to provide the structure needed to adopt digitalisation. Via our within- and cross-case analysis, we were able to identify three influencing criteria observed across the various organisations.

These organisational designs could serve as an informative guide for practitioners in the selection of the appropriate digital supply chain strategy typology. Through the utilisation of both the framework as a blueprint and the determinant criteria as decision making factors, practitioners would be better equipped to adopt digitalisation. This is inherently important not only to retain competitive edge but also to ensure data-driven secure, resilient and sustainable supply chains [89], especially in the face of adversities such as the Covid-19 pandemic.

This research was carried out across twelve multinational companies representing six industries, namely: (i) Aerospace; (ii) Oil and Gas; (iii) FMCGs; (iv) Chemicals; (v) Pharmaceuticals; and (vi) Business and Services, via employing the universal case study methodology. Although this can provide a general overview to understand the digital strategy development across the various industries, a limitation could be the generalisation of the results. Thus, in the future, this research could be carried out on more companies to provide better generalisability. Furthermore, small to medium-size enterprises were not studied as the focus was on multinational companies from the Forbes Global 2000 list. In this regard, future research encompassing small to medium-size enterprises, digital collaboration platforms, and e-marketplaces could be explored to expand the research scope. Except for private enterprises, it could also be interesting to investigate the relevance of the proposed framework on the operationalisation of public policies, such as in the case of digital platforms in agriculture for social welfare [90]. Lastly, this research focused on the development aspect of digital strategies in various manufacturing sectors (i.e., Phase 1, **Fig. 9**). Future research shall expand this scope and investigate the implementation (i.e., Phase 2, **Fig. 9**) and the impact assessment (i.e., Phase 3, **Fig. 9**) of these strategies on individual organisations and end-to-end manufacturing supply chains.

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ANNEX

Table A.I. Results of case studies – Strategy development 5P's.

Analysis Results of Case Studies																				
Company	A		B		C		D		E		F	G	H	I		J	K		L	
Informant / Respondent	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20
Strategy Development – 5P's																				
<i>Plan (PN) – Strategic structured plan from the leadership team as an intended course of action</i>	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₁	t ₁	t ₁	t ₁	t ₁	t ₀	t ₀	t ₀		
<i>Pattern (PA) – A consistent behaviour focusing on actions</i>									t ₁	t ₁	t ₀	t ₀	t ₀	t ₀	t ₀					
<i>Perspective (PE) – An ingrained culture and character of the organisation</i>	t ₁	t ₁	t ₁	t ₁	t ₁	t ₁	t ₁	t ₁	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀					
<i>Ploy (PY) – A decision to outwit competitors through a change in business model or direction</i>																t ₀				
<i>Position (PO) – Strategy is viewed as a mediating force between the organisation and the environment</i>																t ₁	t ₁	t ₁	t ₁	t ₁
<i>Place (PL) – Consideration of institutional distance such as formal and informal impacts</i>	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀	t ₀			t ₀	t ₀	t ₀	t ₀	t ₀		t ₀	t ₀	t ₀	t ₀

Symbol: t₀ – starting point; t₁ – ending point.

Table A.II. Typologies of digital supply chain development strategies.

Data Analysis: Within- and cross-case Case studies demonstrate distinct digital supply chain development strategies																				
<i>Company</i>	A		B		C		D		E		F	G	H	I		J	K		L	
<i>Informant / Respondent</i>	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20
Strategy Development Typologies																				
PN – PL → PE (Top-down)	√	√	√	√	√	√	√	√												
PN – PE → PA (Mixed)									√	√										
PL – PA – PE → PN (Bottom-up)											√	√	√	√	√					
PN – PY → PO (Other)																√				
PN – PL → PO (Other)																	√	√		
PL → PO (Other)																			√	√

Symbol: PN – Plan; PL – Place; PE – Perspective; PA – Pattern; PY – Ploy; PO – Position.