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Revisiting operations agility and formalizing digitalization in response to varying levels of uncertainty and customization

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ABSTRACT

This paper aims to find how digitalization supports inter-organizational purchasing/order fulfillment processes and the required agility to respond to supply/demand uncertainties. The research method includes multiple case studies. Qualitative data are collected via interviews and documentation review. Within-case and cross-case analyses of the research lead to 14 propositions and a novel framework, which formalize and link agility and digitalization at different levels. The research findings point out the agility in micro and macro types for the demand and supply sides of the business, responding to different levels of uncertainties. The findings categorize the relevant applications of digitalization at three levels: data interchange, data integration, and predictive data analytics. Moreover, the agility-digitalization relationships are defined for different levels of customization, represented by customer order decoupling points. This paper contributes to the literature by offering an in-depth and explicit understanding of the impacts of digitalization on different types of agility for different levels of customization.

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Agility; digitalization; uncertainty; customization; customer order decoupling point; big data analytics

1. Introduction

Uncertainties, today, shape the new business norm (Oliva et al. 2019). Relatedly, new operations strategies and advanced technologies have been adopted by firms to cope with uncertainties (Hill and Hill 2017; Pandey, Singh, and Gunasekaran 2021). Among the strategies, agility has been widely used and recognized as an effective operations paradigm for managing uncertainties (Shekarian, Nooraie, and Parast 2020). The agile strategy sets up the firm's resources and processes in a way that enables them to respond quickly and flexibly to demand and supply fluctuations (Inman et al. 2011).

Meanwhile, information systems and digitalization have significantly expanded to offer more visibility on uncertainties surrounding the business and enhance the uncertainty management capabilities of the firm (Shurrab, Jonsson, and Johansson 2022). Digitalization mainly refers to developing/employing digital technologies towards new value-generation business models (Seyedghorban et al. 2020). On the production side of the business, for example, digitalization reduces manufacturing time and cost considerably (10–30%, as reported by Choudhury et al. 2021). On the market side, it has changed the consumer perception and expectation of product/service design, quality, and delivery (Zaki et al. 2019). Digitalization, hence, leads the business towards new directions and landscapes, which demand revised strategies with new dynamism and requirements (Annarelli et al. 2021).

The literature underpinning the agility and digitalization theories and practices and their research gaps (as reviewed in Section 2) shows that the research on and analysis of digitalization and agility interplays are still nascent. It specifically underlines the need for studies on digitalization as a vital prerequisite for different types of agility (Christofi et al. 2021; Ravichandran 2018). Recent reviews also call for further research, beyond the general contributions of technologies, towards more specific impacts of digitalization on operations strategies and how those technologies can be incorporated into the existing systems (Raji, Rossi, and Strozzi 2021; Tortorella, Miorando, and MacCawley 2019). The research calls echo earlier demands for a more fundamental review and redesign of business processes to host advanced technologies (Hammer 2015). Furthermore, Sharma et al. (2021) ask for future research on the effect of manufacturing and customization strategies, such as make-to-stock, make-to-order, and engineer-to-order on the choice of agile practices.

Given the above-mentioned research needs and gaps, this paper addresses the following research question: *How does digitalization affect operations agility?* and more specifically *How do different levels and modes of digitalization contribute to different types of operations agility in responding to varying uncertainties?*

Accordingly, the research objectives are:

i. To revisit different types of agility in response to different supply and demand uncertainties.
ii. To identify digitalization approaches in agile response to customer needs (i.e. agile order fulfillment).

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iii. To explore different levels and modes of digitalization and their effects on different types of agility.

Focusing on the business-to-business purchasing and order fulfillment process context, this paper explores and defines various levels and types of uncertainty, agility, and digitalization, and their interrelatedness. The scope of this research, on digitalization's impacts on meeting customer needs through agile order fulfillment, includes shipment, delivery, production, and supply management practices and their associated uncertainties. The uncertainties are also examined through the customer order decoupling point (CODP) lens where product customization is considered in the forms of design-to-order (DTO), make-to-order (MTO); and ship-to-order (STO) (Rudberg and Wikner 2004)—see Section 2.1 for details.

Through meeting these objectives, the paper offers the following contributions to the literature (full details are discussed in Section 7). By revisiting the applications and implications of agility for various CODPs, this research extends the literature's understanding of the firm's agility in response to demand and supply uncertainties at different levels, labelling them as micro agility (referring to agility in managing individual orders' uncertainties) and macro agility (referring to agility in managing demand uncertainties as a whole). This paper offers 14 propositions (*1a&b*, *2a&b*, *3a&b*, *4a&b*, *5a&b*, *6a&b*, *7*, and *8*), forming a novel framework for implementing different levels and modes of digitalization for different types of agility. The research outcomes then manifest how the digital transformation from data interchange to data integration and towards Big Data Analytics (BDA) can significantly affect the firm's micro and macro agility.

Following the study background and literature review in Sections 1 and 2, the research is designed around three case studies in the clothing industry and based on qualitative data collected through interviews and the companies' internal documents, as described in Section 3. Sections 4 and 5 then present and explain the research findings through within-case and cross-case analyses, followed by discussions and propositions in Section 6. Finally, concluding remarks, the research contributions, and limitations are provided in Section 7.

2. Literature review

2.1. Business uncertainty and agility

The literature on agility is extensive and addresses a range of topics, such as agility preliminary requirements (Qrunfleh and Tarafdar 2013; Swafford, Ghosh, and Murthy 2006), drivers (Khan et al. 2009), contributions to performance (Blome, Schoenherr, and Rexhausen 2013; Margherita, Sharifi, and Caforio 2021), relevance to different products and business environments (Centobelli, Cerchione, and Ertz 2020), and connections with business sustainability (Yusuf et al. 2020). A broad, general insight into agility can be found through recent systematic reviews of Artificial Intelligence (Al Humdan et al. 2020; Centobelli, Cerchione, and Ertz 2020; Patel and Sambasivan 2022).

The scope and impact of agility go beyond the organizational boundaries and include external processes, such as order fulfillment and delivery in downstream, and sourcing and production in upstream supply chains, where rapid alignments of decisions and actions (e.g. on capacity change) are needed to respond to the demand and supply turbulences (Boubaker et al. 2022; Gligor, Esmark, and Holcomb 2015). Relatedly, agility is defined based on multiple dimensions including responsiveness, quickness, flexibility, competency, collaboration, proactiveness, market sensitivity, customer focus, velocity, and visibility (Aslam et al. 2018; Eckstein et al. 2015; Gligor, Holcomb, and Stank 2013; Zhang and Sharifi 2007). Oliva et al. (2019) summarize those dimensions into three key features for agile systems: *dynamic flexibility* to respond to the changes' diversity, *dynamic speed* to respond to the changes' pace and their demand for quick actions, and *dynamic sensing* to detect changes in the supply and demand markets. These enable the firm to swiftly handle changes in the supply and demand as well as alterations in the product and its specifications (Tarafdar and Qrunfleh 2017).

More explicitly, agility is defined as an operations strategy aiming to keep the firm quick and flexible in responding to markets' and supplies' *various*, *sporadic*, and *unpredictable* changes (Lee 2002; Shams et al. 2021), hence it fits the high uncertainty, high variety environments (Biçer, Hagspiel, and De Treville 2018). Naughton, Golgeci, and Arslan (2020), Mohiuddin Babu et al. (2022), and Overby, Bharadwaj, and Sambamurthy (2006) also point out that the business environment uncertainty is the main motive for the agile strategy. The uncertainty is perceived in the size, conditions, and requirements of supply/demand markets, cost factors, competition, evolving technologies, and changing products (Gligor, Esmark, and Holcomb 2015; Mero and Haapio 2022; Napoleone et al. 2021; Yi, Ngai, and Moon 2011).

Since there are uncertainties at various levels, each uncertainty may need a different type of agility to respond to it. The literature principally focuses on the agile response (e.g. higher stock level and local sourcing) to demand trend fluctuations and supply continuity risks, but omits uncertainties in each customer order or supplier delivery (e.g. changes in a delivery size or address of an individual order when it has already been shipped). Ramos, Patrucco, and Chavez (2023) call for future research to examine different levels of uncertainty and their links with different types of agility.

Uncertainties are also affected by product customization levels and their associated CODPs, e.g. MTO (Fogliatto, Da Silveira, and Borenstein 2012). Gosling, Hewlett, and Naim (2017) find the CODP to be a supply chain stage that deals with a high level of uncertainty. While in STO, the shipment size, timing, and terms are subject to change, in MTO the product configuration or features alter commonly, and in DTO the product design remains unknown until all details are agreed on with each customer. CODP uncertainties are derived from customer expectations, order requirements, delivery lead time, and changing product design and features (Datta and Christopher 2011; Gosling, Naim, and Towill 2013; Meisel and Bierwirth 2014; Rudberg and Wikner 2004). In view of that, the CODP should be considered more explicitly in the agility research (Sharma et al. 2021).

2.2. Information technology (IT) and digitalization impacts

Consistent with the dynamic flexibility, speed, and sensing capabilities expected from agile systems (addressed in 2.1), the literature emphasizes the crucial role of products/processes information systems and digitalization to achieve agility (Swafford, Ghosh, and Murthy 2008) in different scopes, levels, or forms: organization (Bottani 2010; Tallon and Pinsonneault 2011), operations (Huang et al. 2012), capacity (Liu et al. 2013), and supply chain (Power, Sohal, and Rahman 2001; Swafford, Ghosh, and Murthy 2008; White, Daniel, and Mohdzain 2005); and in various industries—e.g. see case studies in manufacturing, fashion, and health sectors in Fayezi, Zutshi, and O'Loughlin (2015), Masson et al. (2007), Nabelsi and Gagnon (2017), respectively.

Agile firms need market data to capture the demand status and trends, and detect any change in them as quickly as possible (Dubey et al. 2021; Kim and Chai 2017). They also need up-to-date information about consumer behaviour and preferences, competitors' actions, market opportunities, and environmental forces—which necessitate timely information sharing with customers and suppliers (Li et al. 2006; Mondragon, Lyons, and Kehoe 2004).

In this vein, information systems and digitalization have been found largely supportive to sense the market (DeGroote and Marx 2013) and respond to its changes at operational (e.g. ad hoc response) and strategic (e.g. infrastructure expansion) levels (Lowry and Wilson 2016; Overby, Bharadwaj, and Sambamurthy 2006).

Digitalization, as the primary force behind Industry 4.0 (Skare and Soriano 2021), has advanced innovative business models (Zangiacomi et al. 2017), enabling agile systems to respond to emerging and changing business trends and uncertainties. Digitalization attributes with various levels of sophistication (Tiago et al. 2021) are very much in line with the main features of agile systems, including being 'market-sensitive', 'network-based', 'integrated', and 'virtual' (Centobelli, Cerchione, and Ertz 2020). Business market sensitivity is supported through digital real-time market data capturing, consumer behaviour detection, and enhanced demand forecasts (Jacobsen and Tan 2022). Digitalization then facilitates data interchanges within the agile system, supporting a virtual, well-integrated network of internal/external entities and business units (Monahan and Hu 2015).

Various manifestations of digitalization have been found to back agility—e.g. see studies on cyber-physical systems and inter-machine connection (Rosin et al. 2020; Sanders, Elangeswaran, and Wulfsberg 2016), IT capability and integration (Ngai, Chau, and Chan 2011; Yang 2014), real-time analysis and sharing of information (Akhtar et al. 2022), blockchain (Martínez et al. 2022), data science (Saura 2021), and BDA (Barlette and Baillette 2022). Solheim et al. (2022) generalize the digitalization-agility interplays and indicate that agility depends on the level of digitalization. A summary of our extensive review of the literature is shared in Figure 1, where the impacts of various features of IT and digitalization on different types of agility are mapped against their relevant references.

Despite the mainstream research indicating IT's and digitalization's positive effect on agility, there are studies that do not support such an effect. For example, information visibility is not found to be related to agility in Brusset (2016), and Liu et al. (2013) reject the hypotheses on IT infrastructure and assimilation impacts on supply chain agility. Chakravarty, Grewal, and Sambamurthy (2013) show that IT is effective only in environments with high dynamism and market fluctuations. Škare and Soriano (2021) emphasize the gap in research on the link between digitalization and agility to respond to market changes, while effective digitalization may need a redesign of the organization's business processes (Bonnet and Westerman 2021). In view of these, the impact of digitalization on agility still needs further investigation.

In addition to the market sense and response to its changes, agility still needs further research on digitalization technologies that facilitate inter-organizational collaborations—e.g. production and inventory data exchange (Sanders 2007; Saraf, Langdon, and Gosain 2007). Other studies also call for new approaches to digitalization to support agility (Monahan and Hu 2015) and encourage innovation in information sharing in the agile supply chain (Kim and Chai 2017). More recent ideas for future research recommend studies on different types of digital competencies (particularly advanced technologies, such as BDA) and their effects on different types of agility (Ciampi et al. 2022). Figure 2 summarizes the literature review of this research and specifies the existing gaps in the agility and digitalization literature.

3. Methods

Research into digitalization, uncertainties, and changing operations strategies is emerging and calling for more explorative studies (AlNuaimi et al. 2022; Annarelli et al. 2021). Thereupon, this paper adopts an inductive, qualitative approach and embraces multiple case studies (Eisenhardt and Graebner 2007; Yin 2017). This research design provides the opportunity for an in-depth investigation of the research objectives through documentation reviews and interviews. Studying multiple cases also enables theoretical reflections on the findings, leading to an adequate level of results generalizability (Stake 2013).

3.1. Case selection

Following Miles, Huberman, and Saldana (2020) instruction, and given the research scope and objectives, this paper focuses on three polar cases to include a wide range and different levels of CODPs and the uncertainties around them, as well as different types of operations' agility and digitalization used (or to be used) to manage the uncertainties.

The choice of case studies follows the *theoretical sampling* approach for rigorous case-based research (Eisenhart 2009; Miles, Huberman, and Saldana 2020), which ascertains the research findings' reliability and validity. The case selection process consists of the following steps.

First, case selection criteria (as exercised by similar leading studies, such as Cole and Aitken 2019) are set by the

IT/ Digitalization features	Agility Scope				
	Organizational Agility	Market-side Agility	Operational Agility	Supplier side Agility	Decision Making Agility
IT flexibility IT integration		Bargshady et al. (2016); Gao et al. (2020)		Swafford et al. (2008)	
IT infrastructure capability		Lu and Ramamurthy (2011); Mao et al. (2015); Ravichandran (2018); Chakravarty et al. (2013)			
IT business-spanning capability IT proactive stance		Lu and Ramamurthy (2011); Mao et al. (2015)			
IT exploration IT exploitation		Zhen et al. (2021); Cepeda and Arias-Pérez (2019)		Cepeda and Arias-Pérez (2019)	Zhen et al. (2021)
IT managerial capability IT technical capability		Panda and Rath (2016); Cepeda and Arias-Pérez (2019); Ravichandran (2018); Chakravarty et al. (2013)		Cepeda and Arias-Pérez (2019)	
IT capability: sensing IT capability: reconfiguring IT capability: learning IT capability: integrating IT capability: coordinating		Mikalef and Pateli (2017) DeGroote and Marx (2013)		DeGroote and Marx (2013) Dubey et al. (2021)	
IT competency: digitalization		Vagnoni and Khoddami (2016); Sambamurthy et al. (2003); Ravichandran (2018)		Vagnoni and Khoddami (2016); Sambamurthy et al. (2003)	
IT capability: objects		Cai et al. (2019)			
IT capability: knowledge IT capability: operations		Cai et al. (2019); Overby et al. (2006)			
IT assimilation		Martínez-Caro et al. (2020)			
C:\Users\Suresh.SN\Desktop\Artwork\2024\Feb\15-02-2024\WJOR-2320437				Fayezi et al. (2015) Kim and Chai (2017) Li et al. (2006) Masson et al. (2007) Nabelsi and Gagnon (2017)	
E-commerce capability		Lin et al. (2020)			
Cloud infrastructure, flexibility & integration				Liu et al. (2018)	
Internet of Things		Akhtar et al. (2018)			
Big Data	Wamba et al. (2020)	Ghasemaghaei et al. (2017)			
Big Data infrastructure, flexibility, and management capabilities	Rialti et al. (2019)				
Big Data capability: sensing and responding			Barlette and Baillette, 2022)		
Blockchain	Sheel and Nath (2019) Rane and Narvel (2021)				
Knowledge Management		Côrte-Real et al. (2017)			

Figure 1. Summary of the literature on IT and digitalization features' contributions to various types of agility.

research team (i.e. the authors), based on the research objectives, scope, and approach. The criteria include:

- The case should deal with demand and supply/capacity management practices.
- The case should have uncertainties in its capacity and/or demand planning decisions and actions (i.e. if the production and market environment are very stable for a candidate case company, it is not a good choice for this research).
- Evidence of strategies or actions in response to operations uncertainties should be available (note: the company should not necessarily use the terms 'agility' or 'strategy' in what they do. However, an initial assessment should identify if the candidate company has any plan/action to manage its operations uncertainties).
- The case should have evidence of working with other parties in its upstream or downstream supply chain (note: this helps the research to investigate the CODP and product flow, which often go beyond the company's boundaries).
- The case should have an information system(s) or digital platform(s) to support its operations and communications internally and externally with buyers, suppliers, or other business partners.
- The selected cases should be diverse, in terms of their CODPs, product customization, and the operations uncertainties they face. This is essential to explore, compare, and contrast different strategies adopted in response to various uncertainties.

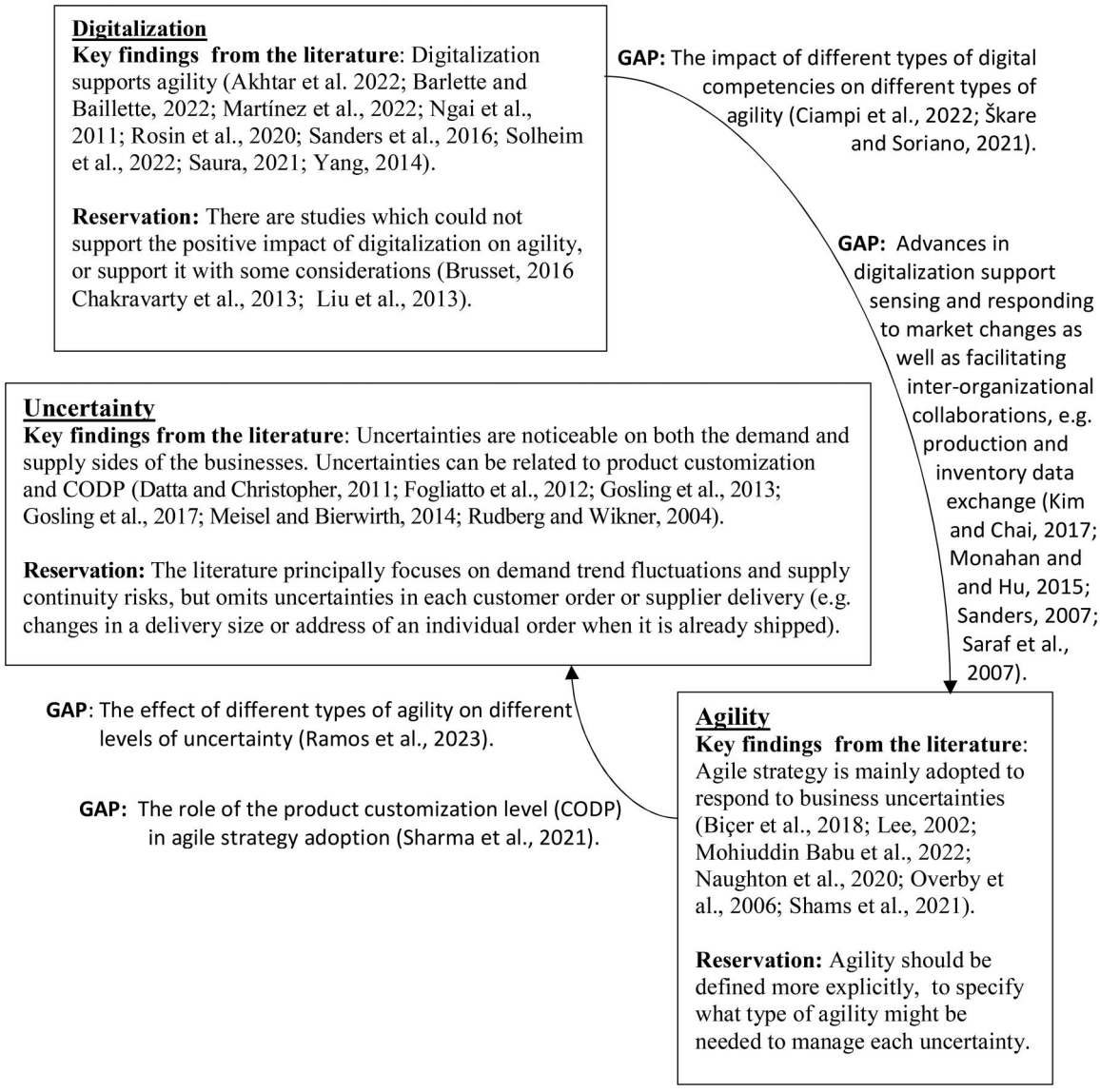

Figure 2. A summary of the literature, highlighting the research gaps.

Subsequently, after going through a long list of eleven companies (originally picked from an extensive business network of the research team) and then a short list of five companies (picked through an initial assessment against the case selection criteria), three case companies are selected. The cases, labelled as Company Alpha, Beta, and Gamma as listed in Table 1, are from various parts and sectors of the clothing industry and meet the case selection criteria very well.

The choice of all cases from one industry does not limit this research and its contributions, since (a) the cases are quite diverse in terms of their products, customers, and order fulfilment process; (b) the clothing business is representative of high uncertainty and multi-echelon industries (e.g. see Purvis, Gosling, and Naim 2014; and Wen, Choi, and Chung 2019); (c) the industry has pioneered the application of operations strategies (such as agile) to respond to various demand and supply uncertainties—e.g. see studies on clothing/fashion designers, producers, and retailers by Bruce, Daly, and Towers (2004), Camargo, Pereira, and Scarpin (2020), Jahed et al. (2022), and Müller, Hoberg, and Fransoo (2023); and cases of ZARA, H&M, and Benetton (Martínez, Errasti, and Rudberg 2015; Mehrjoo and Pasek 2016; Sardar and Lee 2015; Wells and Danskin 2014), where operations strategies, particularly agility, are implemented through vertical integration, postponement, and mass customization, which have been widely adopted by other industries; (d) the clothing business has extensively been engaged in the move towards digitalization (Noris et al. 2021)—e.g. see applications of AI, omnichannel retail, machine learning and simulation, and digital twin, in the clothing and fashion sectors, reported by Mohiuddin Babu et al. (2022), Saghiri and Mirzabeiki (2021), Wang et al. (2023), and Yu et al. (2023), respectively. Major apparel brands, such as Levi's, Uniqlo, Hugo Boss, and Gucci have also advanced their business towards digitalization (Bean 2022; Delesline 2023; Halliday 2023; Marr 2022); and (e) the business processes, operations, and technologies, observed in the case companies are very similar to the

Table 1. Case companies' summary profile and sources of data.

Case key information			Data sources		
				Interview logs	
Company	Products	Customers	Documents	Interviewee (experience[+])	Mode[*] [Duration[**]] {Follow-up[***]}
Alpha	Men's uniform suits and shirts	Large companies and schools	List of customers in the last 10 years. Purchase orders, for the last 6 years. Company's extranet guidelines. List of main suppliers	Production deputy (20+)	F [70′] {1}
				Purchasing manager (10)	T [90′] {2}
				Marketing manager (6)	T [70′] {0}
				Web-team lead (4)	V [120′] {2}
Beta	Athletic clothing	Athletic clubs, youth clubs and gyms	List of customers in the last five years. Purchase orders for the last 2 years. Catalog of designed products for the last 5 years. Company's digital strategy. Company's IT manual.	R&D manager (12)	T [45′] {0}
				Product design team lead (9)	V [70′] {1}
				Marketing manager (3)	F [85′] {2}
				Key account manager (14)	F [120′] {1}
				E-commerce manager (5)	V [85′] {1}
Gamma	Men's under-clothes	Dedicated wholesalers	Product list. Warehouse management system documents. Order delivery logs. Customer feedback/ complaints logs.	Operations manager (10+)	T [65′] {1}
				Warehouse supervisor (19)	T [65′] {0}
				Logistics team lead (8)	F [120′] {1}
				IT director (8):	V [100′] {2}

[+]Years.
[*]Interview mode—F: *face-to-face*; T: *teleconference*; V: *Video conference*.
[**]Minutes.
[***]Number of follow-ups.

industry norms globally, hence the research outcomes are expected to have an acceptable level of internal and external validity.

The selected cases are medium-sized companies (~300 employees) with production and packaging facilities, selling their products in local markets as well as in neighbouring countries (two to five countries). Their customers are businesses (not the final consumer), and the specific focus in each case study is on the process of customer order fulfillment, including receiving the customer order, production, delivery, as well as material/service sourcing and product design if needed. The case companies' key data are summarized in Table 1.

Company Alpha's products include men's uniform suits and shirts which are typically ordered by large corporations or schools. The orders are generally diverse, and each order should be individually taken care of in terms of product specifications. Company Beta's products include various types of athletic clothing which are ordered by sport/youth clubs and gyms. Company Beta often needs to work on a new design for each order. Company Gamma is a mass producer of men's underclothes, which sells its products only to its dedicated wholesalers.

3.2. Data collection

The research data are collected from the companies' documents and interviews with the relevant managers in each company (see Table 1), to identify the companies' experience, decisions, actions, and plans for managing customer expectations, responding to uncertainties, and moving towards digitalization. The companies' documents and interviews have provided this research with sufficient data, assisting it to triangulate the findings.

The companies' documents mainly include product, customer, and supplier lists; customer orders and shipment records; customer feedbacks; and dispute reports (see Table 1 for details). These documents provide historical data on the companies' strategies and performance, and their reports on the previous, current, and future digitalization programs.

The interviews seek more in-depth knowledge and views of the companies' managers around the main themes and objectives of this research. The interview method is recommended as an essential source of case study data (Yin 2017) and has a very good potential to generate rich data to explore advanced research topics and achieve a thorough perspective about them (Tracy 2019). It has also been widely used by similar studies, such as those of Butt, Ali, and Govindan (2023), Mohiuddin Babu et al. (2022), and Rauniyar et al. (2023). In this research, the interviewees are suggested by the companies' top management, as the most knowledgeable, relevant people to the digital technologies as well as order fulfillment processes. The interviews are conducted in a semi-structured format, face-to-face, *via* telephone calls, or video conferences; each takes from 45 to 120 min.

The interview question guide (Table 2, first row) is developed by the research team through several brainstorming meetings. It is then peer-reviewed by two scholars in the same field of research, and the necessary adjustments are made following their comments. The interview questions address the overall business of the company, including its products/customers/suppliers, the main uncertainties they deal with, order fulfillment business processes, the company's decisions and actions against uncertainties, and the company's past/current/future plans and actions towards digitalization and their achieved or expected outcomes. Furthermore, following the useful guidelines of the qualitative research literature (Hennink, Hutter, and Bailey 2020; Jiménez and Orozco 2021), the interview protocol (Table 2, second row) is used to ensure data collection consistency across all cases and enhance the research outcomes' reliability. Interviews and the companies' documents review have been conducted by two researchers (authors) of this paper and their well-trained three research assistants. Follow-up contacts are made with interviewees, wherever further details or clarifications are needed about the interview questions and answers.

Overall, the internal validity, external validity, and reliability of data collection are explained as follows:

- Multiple sources of data (interviews and the companies' documents) establish a chain of evidence and strong cases of triangulation. Besides, during the composition of the study, interviewees review the findings and propositions of the study and provide feedback on them. Theoretical associations are then made within and between cases.
- For external validity, during research design, case sampling is done using robust criteria according to the research objectives. Hence, three case studies with different products in the clothing sector are focused on, and in each case, different types/levels of uncertainty, agility, and digitalization are identified.

Table 2. Interview core questions, and condensed interview protocol.

Main guiding questions:

How do your customers learn about your product/service profile?
How do you receive the customer order?
How do you predict the demand or the main trends in the future customer order?
How do you communicate the received orders from customers with them (in terms of availability, adjustment, and change)?
Does each order have unique delivery terms and conditions (e.g. delivery location, delivery timing, packaging, and pack size) or are they all the same?
Does each order have unique product specification requirements (e.g. colour and material) or are they all the same?
Does each order have unique product design requirements or are they all the same?
Who are your main competitors? Do you compete with them for a lower price, better quality, or … ?
How do you fulfill each order?
How do you handle last-minute changes in the customer order—and in the case that the customer changes the order after it has been agreed on?
How do you purchase your required materials and services from your suppliers? (general description).
How do you handle a supplier's poor performance (e.g. in terms of quality or delivery)?
How much of your activity on the demand side (i.e. receiving, communicating, and shipping orders) is digitalized?
How much of your activity in the production and order preparation (i.e. receiving, communicating, and shipping orders) is digitalized?
How much of your activity on the supply side (i.e. purchasing goods/service from suppliers) is digitalized?
What have been your main challenges in order fulfillment in the last five years?
How have you managed those challenges? Please address information and digital technologies, if they are part of your solutions.
How has digitalization helped you to improve the order fulfillment process?
What are your plans to expand the digitalization of the order fulfillment process?

Interview guidelines:

- The interviewee should be informed about the research project in advance.
- The interview is recorded only if the interviewee agrees.
- Each interview starts with a short introduction, followed by any clarification, which might be needed by the interviewee.
- Not all questions are relevant to each interviewee. The question list should be adjusted before each interview.
- Questions should not be rushed if the answers are lengthy but relevant. If all questions are not answered at the end of the interview, arrange for a follow-up meeting/call/email.
- During the main part of the interview, first general information is to be obtained about the company's business environment, operations model, strategies, and customer/product profiles.
- During the interview, order fulfillment, customer/supplier relationship management, product design, and production processes (whichever applicable) should be obtained and briefly mapped, using flow charts and data flow diagrams.
- Available documents, supporting the questions should be taken during or after the interview).
- The interview notes should be checked and reviewed with the interviewee at the end or later, if needed.

- For reliability, an interview protocol is developed. It includes a list of interview questions designed according to the research objectives and is followed throughout the data collection stage.

3.3. Data analysis

All the interview transcripts and written answers are gone through for descriptive and content analyses (Yin 2017). The descriptive analysis, based on the interviews and the companies' documents, informs this research of the business model(s) of each company, its customer expectations, the relevant order fulfillment processes, and the challenges it faces in managing the uncertainties around them. It also provides an overview of the digitalization approach(es) and solution(s), adopted by the company. This is followed by the content analysis procedure (Krippendorff 2018), where the interview transcripts and notes are coded, and the relevant quotes are extracted from them.

The coding is done by two authors of this research, each with more than 20 years of experience in qualitative research, and also several years of experience in working with various businesses in the manufacturing and service sectors. The coders have an in-depth knowledge of operations strategies, lean and agile production systems, digital transformation procedures, and supply chain risk and uncertainty management, with track records of research and publication in those fields. In view of that and based on another round of review of the recent literature and the interviews' transcriptions, the coders, who work separately, come up with a tentative set of coding keywords. The relevance, rigour, and distinction of the keywords are assessed and discussed by the research team. The necessary adjustments are made to the coding keywords consequently. The coders then double-check the modified coding keywords to make sure they are as exhaustive as possible and the interview transcripts have frequent use of them. The final coding keywords list is organized into nine clusters, as listed in Appendix A—which presents their links with some illustrative quotes too.

Accordingly, the coders analyze the interview transcripts, and the findings reveal four main themes: 'business operations model', 'Problems/Solutions', 'data management/digital transformation plans', and 'future digitalization and enhanced agility' (as shown in Appendix A).

The data synthesis, coding, and analysis process of this research adequately meets the reliability requirements of such research (Krippendorff 2018). The *stability* of the coding and analysis is ensured through multiple rounds of tests and retests, hence the codes and themes identification and definitions would lead to the same results should they be repeated. *Reproducibility*, known as a stronger measure of reliability, is ensured by involving two coders and the third author of the research team, who worked on the contents separately and independently. The intercoder agreement is also measured by the KAlpha coefficient (Krippendorff 2011), where the themes extracted/allocated by coders 1 and 2 are compared with each other. The resulting KAlpha is 0.855, which is higher than the recommended threshold of 0.8.

The outcomes of the content analysis are used for within-case and cross-case analyses of this research. Within-case analysis (Section 4) for each company includes its business operations model; past problems; data management and digital transformation plans; and enhanced agility and future digitalization, extracted from the companies' documents and interviews. Direct evidence for each part of the within-case analysis can be found in the quotes, provided in Appendix A—following Pratt's (2009) guideline.

In cross-case analyses (Section 5), similarities and differences among the cases are identified, and the companies' demand pattern, order qualifiers/winners, CODPs, problems, agile solutions, data workflows, and digitalization solutions are compared and contrasted through a matrix mapping analysis (Miles, Huberman, and Saldana 2020).

Further analysis and discussions on the research results (Section 6) lead this paper to recommend its research propositions, through an inductive approach (Kaufmann and Denk 2011). The propositions are developed through brainstorming sessions by the research team, in multiple rounds, starting with more generic ones and concluding with a total of 14 explicit and distinct propositions (and sub-propositions).

The workflow of this research, including all main steps of data collection and analysis, and their associated section in this paper, is summarized in Figure 3.

4. Within-case analyses

4.1. Company alpha

4.1.1. Business operations model

The main design and cut patterns of Company Alpha's products (i.e. men's uniform suits and shirts) have a limited range and do not change frequently. But they can be largely customized in terms of colour and material grade (i.e. 'premium', 'high', and 'basic' quality of the fabrics). While Company Alpha offers its customers a competitive price, it also needs to make and deliver each order within the agreed time period, which is usually short. In addition to delivery time, the company needs to make sure that the product configuration and quality meet the customers' expectations.

Company Alpha's products are sold to a wide range of business customers, whose demands, in terms of order quantity and product quality, and colour mix, are very heterogeneous. Therefore, predicting the market demand in terms of the type and size of each order is almost impossible. However, the total demand size does not have a major change year by year, hence predicting the overall capacity and total resources required annually is possible.

Order fulfillment process, in this case, can be considered as a make-to-order system, in which Company Alpha makes the products according to each order's specifications and instructions, which can be customized around the quantity, colour, fabric type/quality, and delivery location and schedule.

4.1.2. Past problems/solutions

Company Alpha always intends to fulfill orders properly according to their specifications and schedules, meanwhile

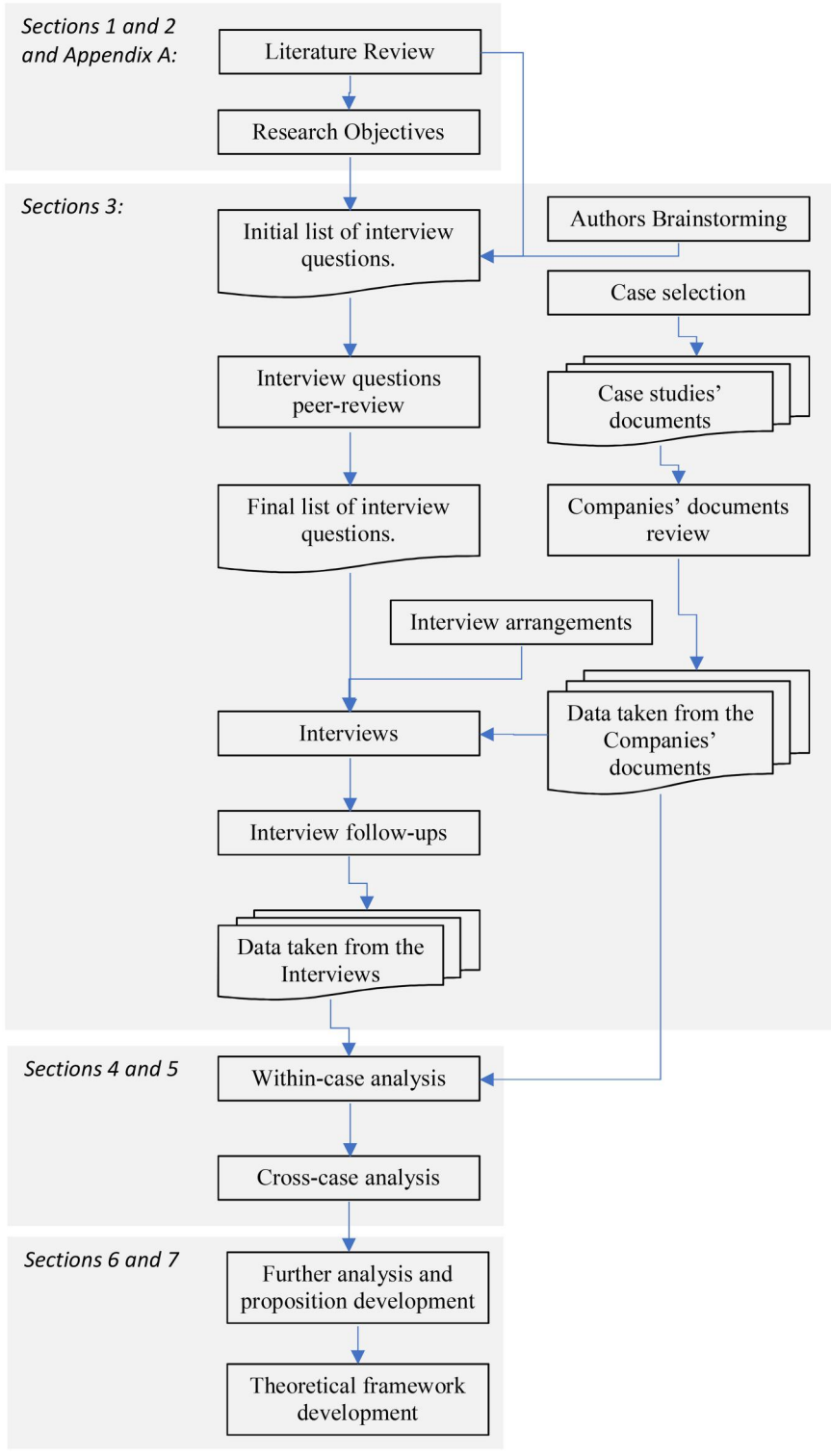

Figure 3. The research work-flow.

facing several challenges, such as misunderstanding of orders received, alterations in the order (after an earlier agreement), poor communication and collaboration between Company Alpha and its customers, disputes on product quality, unclear production quality control procedures, and delays in receiving raw material from suppliers.

To manage those problems and to meet its customers' expectations, Company Alpha has tried to spend more time with the customers to define and clarify each order and its required specifications in detail. It also convinced the customers to limit the quality inspections on their received items by introducing product and process control systems within its own production facilities, where the relevant customers could have access to their quality control reports. Although these actions generally reduced some disputes, misunderstandings, and product quality problems, they added an excessive workload to

Company Alpha, which eventually affected its competitiveness in terms of cost and time. The problems around delayed raw material from suppliers were also tackled by holding extra buffer inventory by Company Alpha. This gave the company good agility to manage various orders quickly, but it caused extra inventory capital and holding costs as well.

4.1.3. Data management and digital transformation plans

Although Company Alpha found its agile actions in responding to its diverse market very helpful, it also found them to be economically unsustainable. Several meetings and ad hoc arrangements for each order, going through all technical and contractual details individually (with the customer, by the product designers and account managers), and holding a large stock of raw material to hedge against supplier delay, were found to be the causes of Company Alpha's operational and financial inefficiency.

Manual interventions, ad hoc decisions, several repetitions in handling and fulfilling the customers' orders indicate a lack of standardized operational procedures and integrated data transactions. The existing workflow and data communication and management systems around Company Alpha's order fulfillment process included: (a) paper-based catalog of Company Alpha's products that customers could go through and review; (b) ordering process which involved meetings between Company Alpha's sales representative and the customer, and paper-based product order forms to be completed by the sales representative and confirmed/signed by the customer; (c) quality control and inspection reports, which were prepared during the production and preparation of each order and kept in the order documentation system, and could be seen by the customer upon request; and (d) financial transactions which were arranged according to the agreed terms of the order and order delivery, and paper-based purchase orders and invoices. Complaints and disputes were usually discussed *via* phone or in meetings and in some cases led to delayed payments by the customer.

The product catalog was usually updated every two years, and the latest edition was distributed to existing and potential customers by mail. It was also presented in exhibitions and sent by special delivery to those who were asking for it. Order forms, their relevant quality control evidence, and their financial records were kept in Company Alpha's orders' physical archive, with secure access.

To manage the whole process of order definition, agreement, production, delivery, and payment, Company Alpha found it necessary to have a well-designed information system to standardize the workflows, decisions/actions procedures, and data transactions. This led the company through a major digital transition project which engaged the company and its customers and suppliers.

On the customer side, the process of marketing and sales went through an essential digitalization. The product catalog, including all product specifications, was digitalized and made available online. Inquiries about products, special requirements, orders, and delivery terms could be made online. Based on an initial understanding of all available options and their initial costs, customers were then able to discuss further details, including the price, with Company Alpha. The order, when agreed upon, had all product specifications, delivery schedules, and payments shared in a secure extranet, accessible only by the customer and Company Alpha. Any amendment to the order, if technically possible, could be requested by the customer *via* the same extranet system, which could be seen by Company Alpha's production and order fulfillment team for a quick reaction or further discussion with the customer.

To enhance product quality assurance, the product and process control procedures (including the quality records and their relevant preventive and corrective actions) were digitalized and shared in the Company Alpha extranet—securely accessible by each customer. This made the product inspections, which had been done by the customer previously, avoidable, leading to much faster product delivery and approval. Finally, Company Alpha's extranet hosted the purchase order, invoicing, and financial arrangements between Company Alpha and its customer, which were accessible by the sales and order fulfillment team.

4.1.4. Future digitalization and enhanced agility

Company Alpha has numerous ideas to employ more advanced technologies to improve its agility. Virtual reality in the sales website, quality control sensors in the production line, and integrating its system through Enterprise Resource Planning (ERP) are the main ideas of the interviewees about the future. BDA can be very helpful for the company too. In this case, the Big Data does not refer to the demand data, since orders are largely divergent, and a simple trend or pattern cannot be identified in them. However, analysis of the factors which may affect the customer's order (e.g. fashion trends) can be very helpful.

Moreover, closer relationships with suppliers, and establishing a supplier relationship management (SRM) digital platform to manage the suppliers' poor delivery performance are among Company Alpha's future plans.

4.2. Company beta

4.2.1. Business operations model

Company Beta has set up its business around the design and production of athletic clothing for athletic/youth clubs and gyms. The products ordered from Company Beta usually need unique designs (e.g. for the sports suits). Innovative design and product quality are the winning factors for Company Beta in the market, although it still needs to manage cost and order fulfillment lead-time since its rivals perform very well in terms of product delivery and price.

Company Beta works on a totally or partially new design for each order. Each design is agreed on by the customer in advance before it is finalized. The order fulfillment process in this case can be considered as a DTO, in which each order is designed, made, and delivered according to the customer's instructions.

Considering the range and diversity of its customers, Company Beta needs to be very agile in responding to

individual customers and their requirements. To this end, the company has made all its services and product designs available online, where the customer can first review them and then contact the sales and/or product design team for further details and make arrangements to place its order.

4.2.2. Past problems/solutions

Company Beta tried to be visible on the Internet to offer its products to a wider range of customers. Although the web-design team spent a great deal of time on designing and maintaining the company's website, the majority of the customers were still those who have been with Company Beta since a long time ago or have been introduced by its existing customers.

When receiving an order, usually *via* phone or email, Company Beta met with the customer to clarify all details of their requirements—depending on the level of customization needed in the product design, they had one or several meetings. Although this process tried to assure a good understanding of the customer's needs, it was usually very lengthy and expensive (particularly if it needed several trips).

Deviation from the promised delivery time was also a cause of customer disappointment—in some cases, a minor delay (e.g. 2 days) led to the athletic club not receiving its ordered sports suits for an important match. To avoid such major problems, Company Beta started to work with some sub-contractors to help it, in the case of limited capacity, to meet a particular order deadline. Although sub-contractors were very helpful for many orders, the quality of their products was not consistent or satisfactory. At some point, the product defect rate reached 4%, which was very high for the industry standard. Although the defects were mostly minor (e.g. missing stitches or small shade variation), they caused many complaints and disputes, and even some of the company's loyal customers started extra inspections on the orders arriving from Company Beta and made a payment only after the inspection approved the product quality—a condition that Company Beta accepted. Less frequent but major problems were also reported when the delivered product did not meet the expected design specifications of the customer. Such problems needed a major rework and caused delays in the order delivery time, and damaged the company's image—in a few cases, the customer cancelled the order and in one case the customer was lost permanently.

4.2.3. Data management and digital transformation plans

The emphasis of the customer on quality and delivery lead-time, alongside the problems that occurred in those areas, required Company Beta to revise its product design, quality management, and order delivery operations, where data visibility and data management were found to be the core. Originally, the dataflows around Company Beta's order fulfillment process had included: (a) web-based catalog of the company's products that customers could browse and review; (b) ordering process which involved meetings between Company Beta's sales and design teams and the customer. Details of the required design and its specifications were agreed upon through several meetings, and the final design would be available in electronic and paper formats; (c) reports of the inspection on arriving orders, conducted by some customers, were sent to Company Beta, and if defective items were found, further actions would be triggered (e.g. asking for an exchange, refund, order cancellation, or even requiring a penalty), and, depending on the severity of the quality problem, one or several meetings might be held between the customer and Company Beta; and (d) payments were made through bank transfer according to the terms of the contract or any further arrangements made after it (e.g. in the case of missing or defective products).

Based on the dataflows listed above, Company Beta focused on a series of digitalization programs to enhance its agility in responding to its diverse demands and to expand its rather stable market share. The sales process was redesigned, and the content and format of the company's webpage were changed to go much further than an electronic catalog and to be a platform to host and manage the sales process. In this way, the webpage was equipped with virtual reality and a customer-led design facility, which let the customer choose their preferred options of design, sketch, colour, print, and sizing of the sports suits. A pilot test showed that about half of the orders could be done entirely online, and only about one-third of the online orders (i.e. $\sim$16% of all orders) needed one or two short follow-up checks to assure and confirm some order details. The other half of the orders needed further clarification and discussion between the customer and Company Beta's sales and design teams. Moreover, an extranet platform was developed to exchange design technical specifications with relevant customers more easily and faster.

To make the quality control process more transparent and assure customers, the latest status of each order and the quality control reports for each stage of its production and delivery were shared with each customer in its dedicated area in the newly developed production flow extranet.

A separate program, an electronic system, was also developed to handle all financial documents and transactions, which worked based on the data it received from the sales and production flow systems and facilitated the payments significantly.

4.2.4. Future digitalization and enhanced agility

Company Beta's ideas to expand its digitalization and agility are mainly around a fully customized and automated system, where the customer can go online and try different designs, configure the one(s) it would like to have, receive a sample, and place the order. The company's digitalization is also planned to be extended to financial agreements.

Moreover, the ability to capture a wider range of data about the influencing factors on demand (i.e. the factors that affect the type of design that Company Beta's customers ask for) and identifying a relevant pattern in them, can be achieved through BDA and will be very useful for the company.

4.3. Company gamma

4.3.1. Business operations model

Company Gamma's products include a limited range of men's underclothes, with a fixed combination of colours. The product design and material (e.g. fabric) are revised very rarely, as the target market does not really ask for much change or innovation. The price is, however, very important and should be kept low and stable. In addition to price, the company has put effort into keeping its products available in the market with consistent quality and protecting its reputation in the market. Company Gamma's products are sold to a few wholesalers, who distribute and sell the products to the market through an extensive range of retailers. Based on their sense and knowledge of the market, the wholesalers plan and arrange their orders with Company Gamma on a regular basis. Order fulfillment, then, follows STO, in which Company Gamma ships the products, using its logistics service provider, as per the customer's (i.e. wholesaler) order and instruction—in terms of shipment quantity, delivery schedule, and delivery location.

4.3.2. Past problems/solutions

Company Gamma always intended to make the product delivery whenever requested by its wholesalers. This did not, however, become a reality. Poor reliability of the delivery services and logistics infrastructures, lack of proper communications between Company Gamma and the wholesalers, limited visibility of the logistics performance and the delivery status, misunderstanding of the orders received, delays in receiving or processing the purchase orders, lengthy procedures of loading and unloading, disputes over deliveries, and last-minute changes (even after the order had been shipped) in the wholesalers' order were the main challenges of Company Gamma's order fulfillment processes.

To maintain its agility in responding to the problems above, and to assure product availability (i.e. preventing any stock-out), Company Gamma was holding safety stocks of finished products—in case it received any unplanned order or any request to change the existing order size.

On the customer side, the increasing costs of warehouses' and stock-keeping points' premises and facilities within or near the sales market (typically big cities) drove the wholesalers to take advantage of Company Gamma's commitment to product availability and minimize their own inventories. Hence, they ordered in smaller batches, more frequently (including more unplanned orders), and with more amendments (to the original order). This increased Company Gamma's product inventories and placed considerable pressure on Company Gamma and its order fulfillment system.

4.3.3. Data management and digital transformation plans

After several years of dealing with its order fulfillment and delivery challenges, and through several problem diagnosis projects, it became evident to Company Gamma that its approach to agility, by keeping finished product inventories, was neither enough nor an ultimate solution. Major problems were identified in communicating and managing data, including product, inventory status, order, shipment, delivery, receiving, invoice, and payment data. The existing data management systems included: (a) a barcode and scanning system to identify and capture product data at the item, box, and pallet levels; (b) an ordering system, based on electronic MS-Word forms which were communicated *via* email; (c) an invoicing procedure, implemented through a standard purchasing order and invoicing MS-Excel template, and communicated *via* email; and (d) a complaint system which was limited to an email address and a telephone line which the wholesalers could contact in the case of wrong, delayed or missing deliveries.

To manage its multiple order fulfillment problems, Company Gamma found it crucial to have much more visibility of product shipment and receiving status, market demand, and inventory status on its wholesalers' sites. In view of that, the company defined two data management programs: (i) a short-term plan to transfer the existing order management forms and procedures to a unified online platform which could improve data transactions *via* email, and standardized data sharing; and (ii) a long-term plan to capture and share the sales, inventory and delivery status data on a real-time basis to achieve higher and broader visibility of demand, supply, and the product flows between them.

In the short-term plan, transferring the old order management activities to an online system took place through an XML extranet system, hosted by Company Gamma, and all ordering activities including the regular and emergency orders, purchase order issuance, invoicing, and the relevant confirmations should go through it. The extranet, which was technically performing as an online Electronic Data Interchange (EDI) system (although it was not named EDI), assured data accuracy and process consistency through a single platform and format for data entry and retrieval.

The long-term plan needed a wide range of technological infrastructure, instruments, and software applications. In the dispatching (from Company Gamma's site) and receiving (in the wholesalers' sites) operations, radio-frequency identification (RFID) was used at the pallet level to identify and capture the product data more accurately. With RFID tags attached to the pallets, RFID sensors can capture all leaving and arriving items (from Company Gamma, and to the wholesalers' sites, respectively), with virtually 100% accuracy. This could minimize any mismatch between the dispatched items and received items, and accelerate those operations significantly. RFID-based data of the leaving item could also be shared with the wholesalers through advanced shipment notice, to reconfirm the shipment and make them ready for delivery.

In addition to the dispatch and receipt points, the satellite navigation devices, mounted on Company Gamma's delivery fleet, identified and shared the real-time location of the shipments, helping the wholesalers to prepare for receiving and unloading operations—not too early or too late.

The wholesalers also agreed to share their relevant inventory data with Company Gamma. This helped Company Gamma to monitor its customers and be proactive in

preparing for their unplanned orders when their inventory level reached the re-order point.

4.3.4. Future digitalization and enhanced agility

Although the recent/current digitalization gives Company Gamma very helpful access to the wholesalers' inventory data, it would be much more beneficial if Company Gamma could forecast the unplanned orders based on the inventory position, before they reach the reorder point. This is possible through BDA where Company Gamma can run predictive analysis. Moreover, access to the inventory data, both in the wholesalers' distribution channels and those of retailers provides Company Gamma with more visibility of the product flows and status across its demand chain and helps it to prepare in advance—for unplanned orders as well as changes in regular orders. Company Gamma is also planning to use the Big Data available about its final consumer market. This can help the company to predict at least some influencing factors on its direct demand instability, and plan for them in advance.

5. Cross-case analyses

This section provides a further in-depth view of the order fulfillment and digitalization strategies and actions of the three case studies, through comparative analyses. This then leads to a higher-level view of agility and digitalization, formulated through 14 propositions.

Order fulfillment processes in all three companies are mainly set up around responding to their customers' demands, which vary in different manners and at different levels. While Company Gamma's demand mainly varies around the order quantity and delivery location and schedule, Company Alpha's and Beta's demands ask for customization in their products' material and design, respectively. To respond to demand and its changing behaviour, all three companies try to be agile, i.e. organizing their capacities and inventories to meet the varying customer orders, with the shortest delivery lead-time. Customer expectations are not, however, limited to delivery lead-time. In all three cases, changes occur in order, albeit in different ways. Given that, there are two levels of uncertainties identifiable on the demand side: (i) macro uncertainty, referring to the unpredictability and fluctuation of demand, traceable in order size and requirements which are changing over time, and (ii) micro uncertainty, referring to ambiguity in and alteration to each order. A proper response to demand also needs to consider other factors alongside demand uncertainty at micro and macro levels—named micro agility and macro agility, respectively. Companies Alpha and Beta have reported problems with product quality. Company Alpha has also addressed the trouble caused by its delaying suppliers, and Company Gamma has reported problems in logistics reliability which disrupts its product delivery. All three cases claim that poor communication and data visibility affect their agility and quick response capability.

Further understanding of the companies' problems depends on a better comprehension of their business market and environment, as well as their strategies in response to those problems. The main requirements of and competing factors in the market, i.e. order qualifiers and winners, respectively (Harrison et al. 2019, 28), have differences and similarities in all three cases. While price and delivery lead-time are shared by companies Alpha and Beta as order qualifiers, the former company needs to focus on product variety and aftersales service to win the market, whereas the latter company mainly competes on innovative design and product quality. It is quite different for Company Gamma, where the order qualifiers are product quality and product availability in the market, and order winners are price and delivery lead-time.

Consistent with the order qualifiers and winners, and responding to the demand type and instabilities, the companies adapt their product/service customizations and order fulfillment strategies in different ways. Company Alpha's product range and main design remain unchanged, although its products and their constituent materials are adjusted and produced according to each order. This level of customization is very much conforming to the MTO strategy. In Company Beta, each order is considered a new project, which needs a fresh product design and delivery plan. Product customization on such a scale needs a DTO strategy. Company Gamma's products do not usually change in their design or style. What the company mainly focuses on is responding to the constantly changing order size and terms (e.g. in terms of location and batch size), which is compatible with the STO strategy.

The three case studies take different approaches to achieve agility in their customizations and order fulfillment strategies. In the cases of customized product material/configuration (MTO) and product design (DTO) (i.e. Company Alpha and Beta, respectively), better communication and more collaboration on defining the order are found to be crucial. While in MTO the focus of the collaboration is more on the product specifications and order terms and conditions, in DTO the collaboration is mainly on product design. In both of those cases, more transparency and data sharing in production and quality control procedures and reports, and flexible order fulfillment capacities are found to be necessary. Order fulfillment capacity flexibility is incorporated *via* holding extra inventory and use of sub-contractors in MTO and DTO, respectively. Excess stock availability is also employed as an evident solution in STO (i.e. Company Gamma).

The case companies' approaches to agility have also been found to be largely relevant and supported by data and digital technologies, without which agility can be very costly, if achievable at all—as explained for each case in Section 4. Digitalization has mainly helped companies to share the product and process data with their customers, communicate with them more effectively, and handle the whole process of ordering and delivery more efficiently.

Future digitalization plans mainly include smarter technologies, such as virtual reality, to define customer orders and

Table 3. Cross-case comparisons.

	Company alpha	Company beta	Company gamma
Demand	Total demand is stable and predictable. Customer orders are unpredictable.	Total demand and customer orders are unpredictable.	Demand is stable, but details of orders (e.g. order size, delivery locations, and shipment schedule) vary for each order.
Order qualifiers (OQ) and winners (OW)	**OQ** Delivery lead-time, Price. **OW** Product variety, Aftersales service	**OQ** Delivery lead-time, Price. **OW** Innovative design, Product quality	**OQ** Product quality, Product availability in the market. **OW** Price, Delivery lead-time
CODP	Make-to-Order (MTO)	Design-to-Order (DTO)	Ship-to-Order (STO)
Problems	Unpredictable orders. Customer alterations in the order (even after an earlier agreement). Misunderstanding the customer orders. Poor communication and collaboration with customers. Disputes on product quality. Unclear production quality control procedures. Delays in receiving raw material from suppliers.	Unpredictable orders. Need for a new design for each order. Complexities in the customer order and specifications—numerous cases of misunderstanding have been reported. Delay in order/product delivery to the customer.	Lack of proper communication with customers. Misunderstanding of the orders received. Last-minute changes (even after the order has been shipped) in the customer's order. Lengthy loading and unloading procedures. Poor reliability of the delivery services and logistics infrastructures. Limited visibility of the logistics performance and delivery status. Disputes over deliveries. Delays in receiving or processing the purchase orders.
Conventional agility solutions	More time spent with the customers to define and clarify each order and its required specifications. Product/process control systems, introduced within the company's production facilities, with reports accessible by the relevant customers. Holding raw material inventory to hedge against supplier delay.	The company's services and product designs made available online. More time spent with the customers to define the required design specifications. Sub-contractors used to support the company's capacity to meet the orders' deadlines. Inspection of arriving items by the customer—the payment to be made after inspection approval of product quality.	Holding safety stocks of finished products.
Solutions Pros (+) and Cons (−)	+ Quicker and fewer disputable product deliveries due to less inspection by the customer, and clearer agreements on orders. − Time-consuming, inefficient ordering process *via* lengthy communications with customers. − Inventory cost	+ Better understanding of the required/available designs and specifications. + Meeting the customer order deadline. − Lengthy communications and meetings with customers to finalize the order. − High product defect rate, leading to a customer complaint. − Company's website not largely contributing to the sales.	+ ∼100% service level (product availability). − Customers push their inventories to the company and place last-minute orders in small batches and more frequently, which urges the company to increase its finished product stock level. − Poor data management and communication with customers (this problem is largely hidden behind the large finished product stock kept by the company).
Existing data/workflows before digitalization scheme	Paper-based product catalog. Ordering process including meetings with the customer—paper-based product order forms to be approved by the customer. Product/process quality control reports, accessible by the customer. Financial transactions, including paper-based purchase orders and invoices.	Web-based catalog of the company's products. Ordering process including meetings with the customer—the final design approved/available in electronic and paper formats. Reports of the inspection on arriving orders, conducted by some customers are sent to the company for further actions about defective items, if any. Payments made through bank transfer, according to the paper-based invoice.	Product identification (at item/box/pallet levels), using barcode and scanning technology. MS-Word order form, to be communicated *via* email. MS-Excel-based purchase order and invoicing system, communicated *via* email. Email/telephone-based complaint system, available for the customer.
Digitalization plans	Products catalog, digitalized and shared online. Online product inquiry. Order keeping and amendment system shared with the customer *via* the extranet. Quality control system, sharing the product/process control reports with the customer *via* the extranet. Customer payment system including online purchase order and e-invoicing, shared with the customer *via* the extranet.	Interactive web-based product catalog, equipped with virtual reality and customer-led design facility. Product design extranet, to exchange the customer order design specifications and amendments. Production flow extranet, sharing the latest status of the order and product quality reports with the relevant customer. Fully electronic customer payment system, integrated with the company's sales and finance.	Online EDI-like unified system, including order placement, shipment information, delivery confirmation, and invoicing modules, accessible by the company's customers *via* the extranet. RFID-equipped shipment, and delivery facilities in both the company's and its suppliers' sites. RFID-EDI integrated system to link ordering and shipment systems with full delivery tracking feature.
How digitalization supports agility	Receiving and understanding customer order and changes in it. Sharing the relevant order requirements with the production team and suppliers. Quality management.	Receiving and understanding customer order and changes in it. Sharing the relevant order requirements with design and production teams. Quality management.	Receiving customer order and changes in it. Sharing the relevant order requirements with the order preparation team and the logistics service provider. Product shipment and delivery.

collaborative product design with customers (as recommended by Companies Alpha and Beta), a more sophisticated ERP system to capture and share the production and quality data with customers and suppliers (as recommended by Company Alpha), and BDA (as recommended by all companies, albeit in different ways). Table 3 organizes further details of the cross-case analyses and comparisons of this section.

6. Discussions and propositions

Based on the individual and comparative analyses of the case studies, this research identified that digitalization contributes to order fulfillment agility in four main stages: receiving a customer order, sourcing and supply management, production and quality management, and product delivery (Table 4). In the 'receiving customer order' stage, digitalization mainly helps in understanding the customer's needs and expectations, taking and processing orders, and handling payments. It may include various virtual reality, AI, and BDA applications and runs through extranet and Internet platforms. In the 'sourcing and supply management' stage, digital platforms, such as cloud-based ERP systems can considerably support collaborations with suppliers. They help the firm to communicate its production and order plans, and any alteration to them, with its suppliers faster and more effectively. This gives suppliers more time to respond to the changes. Digitalization also makes the latest status of the suppliers' production and delivery more visible to the firm, thus any interruption to arriving items can be detected quickly. In 'production and quality management', digitalization, on the one hand, assists internal production planning by providing more visibility of production operations and a smoother flow of production and quality plans (e.g. using cyber-physical systems, robotics, sensors, and the Internet-of-Things); and on the other hand, facilitates communications with customers and suppliers on product design, customer order expectations, and supplier delivery plans (e.g. using a cloud-based system). In the 'product delivery' stage, digitalization helps the physical/data-flows match with each other, where EDI-based systems share the order information and its latest changes, and data capturing and sharing technologies (e.g. RFID, smart tags, and satellite navigation) monitor the latest status of the delivery.

Beyond the general inference of within/cross-case analyses above, the mode and level of digitalization contribution to agility can be investigated in further depth for each CODP and the different levels or types of agility required by each. Earlier, cross-case analyses have pointed out uncertainties in demand at macro and micro levels. The same levels of uncertainties are traceable on the supply side. This is in line with earlier research, raising the need for agility on both supply and demand sides (Lee 2002). Macro uncertainties (in trends and performance on demand/supply sides), as well as micro uncertainties (in each customer order, e.g. alterations made by the customer; or in each supplier shipment, e.g. delays or poor quality), are largely affected by the CODP and its relevant customization strategies. The three cases of this research are mapped against DTO, MTO, and STO customization strategies, with various approaches to digitalization, whose impacts on different types of agility are summarized earlier in Table 3, and discussed below.

In STO, demand-side micro agility is mainly about quick response to urgent orders and last-minute changes in them—in terms of quantity, delivery location, and conditions. A proper and speedy response largely depends on understanding the customer order changes quickly and correctly. Standardized data and data interchange mechanisms (e.g. EDI) between the focal firm and its customers can assure the accuracy and speed of receiving the customer order data, due to less manual intervention and faster data transfer from the customer's procurement system to the seller firm's order shipment system. In view of that, it can be stated that:

> *Proposition 1a.* Digitalization supports the demand-side micro agility of STO systems through swift receipt of orders and delivery alterations data by the focal firm from its customers.

The initial steps towards digitalization can be followed by smart data-capturing tools, integrated inventory/ordering/delivery information systems (connecting the seller firm with its customers), and cloud-based systems (sharing the order and delivery status on a real-time basis), which are known as the main trends of digitalization that help a firm to have proactive access to the order's alterations. Therefore, any drop or shortage in inventories at the customer's site(s) can be detected and shared automatically by smart technologies

Table 4. Digitalization applications to agility in different stages of order fulfillment.

		Agility in			
Initial digitalization solutions	Advanced data and digital technology	Receiving orders	Sourcing/SRM	Production/quality	Delivery
Digitalized/online product catalog	Virtual reality-equipped product catalog	X			
Online product enquiry	AI-equipped product enquiry management	X			
Collaborative product design	Cloud-based customer-led product design	X		X	
EDI, E-Invoicing and E-Payment	Cloud-based integrated order/payment	X			X
Customer order keeping and amendment	management system, BDA	X			
ERP and SRM	BDA: prescriptive and predictive analyses		X	X	
Collaborative production planning	Cloud-based production planning and ERP systems		X		
Production/quality control system	Cyber-physical systems, robotics, Internet-of-Things AI			X	
RFID-equipped delivery system	Smart tags, Internet-of-Things, Satellite navigation			X	X

and integrated systems. This can go up to some extreme cases, for example when the delivery driver is updated and informed to change his route and deliver the order to customer warehouse *Y* instead of warehouse *X*. Therefore:

Proposition 1b. Digital platforms and tools, capturing the customer's inventory and market status autonomously, support the demand-side micro agility of STO systems by proactive analysis and sharing of order alterations data with the focal firm on a real-time basis.

In make-to-order systems, demand-side micro agility focuses on a quick response to unexpected changes in customer orders, in terms of product ingredient, material, and packaging. This needs the firm to understand what exactly the customer is asking for. It also needs the customer to know about the selling firms' capability and the options it can provide to its customers. Digital platforms (e.g. extranets) can significantly facilitate this mutual understanding of the initial order and its subsequent alteration. Hence:

Proposition 2a. Digitalization supports the demand-side micro agility of MTO systems through the swift sharing of customer order alterations data by the customer with the focal firm.

Digitalization also helps the customer and seller understanding of each other's expectations and capacities, through sharing those data as well as standardizing the data—i.e. transforming order and product data into a more structured format (e.g. instead of explaining the required material or product features in a text format, the customer chooses one of the available options in the firm's sales extranet, by ticking the relevant box there). If order and product data need more clarification, they can be supported by further structured data, such as explicit quantitative measures, available *via* digital measurement and visualization tools, rather than qualitative, open-to-misinterpretation texts (e.g. colour description 'light blue' is also accompanied by its RGB code: 46, 172, 242). Succeeding in a clear understanding of customer orders, digital technologies, such as robotics and computer-aided-manufacturing can be integrated within the focal firm-customer ordering and order adjustment system, and speed up the production stage in responding to the changing orders adequately and swiftly. Thus:

Proposition 2b. Focal firm digital access to the customer order receiving/adjustment data supports the demand-side micro agility of MTO systems by real-time sharing of customer order alteration with the focal firm's internal production processes.

In DTO systems, demand-side micro agility needs to find out about and understand further details of the customer order, which changes at the product design level. Customers should also be aware of the available product design options provided by the firm. Because of those requirements, digital platforms (e.g. order placement systems) can significantly support speedy and accurate customer order alteration data interchange. Hence,

Proposition 3a. Digitalization supports the demand-side micro agility of DTO systems through the swift sharing of product design alterations by the customer with the focal firm.

Moreover, collaborative design and advanced technologies, such as augmented and virtual reality, coupled with computer-aided design technology can accelerate the whole process of product design customization and adjustment at a high level of accuracy and transparency. In view of that:

Proposition 3b. Focal firm digital access to the customer order receiving/adjustment data supports the demand-side micro agility of DTO systems by real-time sharing of customer order alteration with the focal firm's internal design and production processes.

Supply-side micro agility is mainly about maintaining a supply-base capable of a quick response to sudden changes in the firm's purchased items/orders as well as the firm's readiness for unexpected disruption in its supply. The dependence on DTO, MTO, and STO systems on suppliers is widely diverse. In STO, the purchased materials from suppliers usually remain the same. The firm's suppliers are not, however, limited to material suppliers. To achieve highly agile deliveries and customized shipments, STO may work with various logistics providers (i.e. service suppliers), while the expectations from them vary significantly and constantly. Logistics service providers need to be informed about the firm's customer delivery expectations as soon as possible, ideally on a real-time basis. Digitalized platforms and tools expedite and enhance the firm's communications with its logistics service. Thus, it can be stated that,

Proposition 4a. Digitalization supports the supply-side micro agility of STO systems through swift sharing of order and delivery alterations, by the focal firm with its logistics service.

Over and above data interchange and the sharing platform between the firm and its logistics service suppliers, digitalization can extend the demand-side integrated ordering/delivery information systems, that connect the firm with its customers, to logistics service suppliers too. This helps the STO's strategic suppliers (i.e. logistics service providers) to have proactive access to the customer's order alteration, helping them to have an agile response accordingly. Therefore:

Proposition 4b. Logistics service digital access to the focal firm-customer order receiving/adjustment data supports the supply-side micro agility of STO systems by real-time sharing of order and delivery alterations with logistics service providers.

In MTO, each purchase order of the firm to its suppliers may be subject to changes, driven by alterations that its customer makes in the product's material or components—which themselves, or their constituent elements, are purchased from suppliers. To be agile against changes in the purchased material and components, suppliers should learn about the changes as quickly as possible. This needs the changes in the firm's customer order to be swiftly communicated to the supplier by the firm. Hence:

Proposition 5a. Digitalization supports the supply-side micro agility of MTO systems through swift sharing of customer order alterations data by the focal firm with its suppliers.

Supplier involvement in the changes will be prompt if the supplier is given access to the focal firm-customer order receiving/adjustment extranet platform. This helps suppliers to be proactive and speedy in an MTO system. Hence:

Proposition 5b. Supplier digital access to the focal firm-customer order receiving/adjustment data supports the supply-side micro

agility of MTO systems by real-time sharing of customer order alteration with suppliers.

Supply-side micro agility in DTO can be supported by digitalization in a very similar way to MTO. In DTO, suppliers may be affected by the firm's product-customized design, which affects the firm's purchased items or even engages suppliers in designing the product. Digitalization accelerates and enhances the firm's communications with its suppliers about the product design and its changes. In this regard, it can be stated that:

Proposition 6a. Digitalization supports the supply-side micro agility of DTO systems through swift sharing of product design alterations by the focal firm with its suppliers.

Digitalization can also move towards a higher level of integration where suppliers are involved in changes in design through access to the focal firm-customer collaborative product design extranet platform. Hence:

Proposition 6b. Supplier digital access to the focal firm-customer order receiving/adjustment data supports the supply-side micro agility of DTO systems through real-time sharing of product design alterations with suppliers.

Unlike micro agility and its focus on alterations within each customer order, macro agility tries to respond to fluctuations from one customer's order to another. Typical digitalization approaches recommended above for micro agility, i.e. to understand customer orders quickly and accurately, do not help macro agility sufficiently since in high uncertainty levels, volatilities in order size or specifications are so high that knowing about them a few hours or even days earlier cannot help the firm very much. The conventional agile strategies of maintaining extra capacity or inventory have been proven to be costly—shown in our case studies, also pointed out by Teece, Peteraf, and Leih (2016).

Macro agility needs more advanced data and digitalization technologies to go beyond dealing with alterations to individual orders or day-to-day changes in market demand. Business intelligence and BDA are employed to identify future patterns and trends in demand and supply markets. In high-uncertainty environments, BDA can be a great help for the market-sensing capability of the organization and assist in a swifter and more accurate identification of risks and threats in turbulent environments.

In an STO, demand-side macro agility tries to equip the firm's production and shipment capacities to respond to the regular changes in the orders' quantity and delivery. Although those changes are typically unpredictable, intelligence about the factors that affect them can drive a causal-type forecast. BDA, by focusing on demand influencing factors, can expand the firm's market intelligence beyond its direct customers and their fluctuating demand. For example, by gathering and analyzing demographic data, a firm can have a good sense of its target market's age groups, well ahead of receiving an order from its wholesalers or retailers. Eventually, this macro-level market intelligence supports the firm's mid/long-term capacity decisions, making them available when/where they are needed.

Similarly, in MTO and DTO, demand-side macro agility business intelligence and BDA help in identifying future market trends, well ahead of receiving orders from the customer. Causal-type forecasting here tries to find out more about the demand influencing factors. Product material and specification, in MTO, and product design, in DTO, are viewed as functions of numerous influencing factors, and if identified and predicted, the customer fluctuating expectations can then be responded to with a higher level of reliability. In view of these:

Proposition 7. Advanced digitalization, including business intelligence and BDA, supports demand-side macro agility by providing it with predictive analytics on the influencing factors on demands' size and location (for STO), product specifications (for MTO), and product design (for DTO).

With a similar approach to managing the demand-side macro agilities, in the supply-side macro agility, BDA of the supply market and its influencing factors expand the firm's intelligence about the availability of its purchased items and services, beyond its direct suppliers and the data they may (or may not) share with the firm. Therefore:

Proposition 8. Advanced digitalization including business intelligence and BDA supports supply-side macro agility by providing it with predictive analytics on the influencing factors on logistics providers' capacity and capability (for STO), suppliers' production capacity and capability (for MTO), and suppliers' design capacity and capability (for DTO).

Figure 4 organizes the research propositions according to digitalization contributions to demand-side and supply-side micro/macro agility in DTO, MTO, and STO systems.

7. Conclusions

This research has studied the role and effect of digitalization on agility, by identifying different types of agility (i.e. demand-side *vs.* supply-side and micro agility *vs.* macro agility) and exploring the contribution of digitalization to them in different CODPs (i.e. DTO, MTO, and STO).

Through three case studies in the clothing industry, this research has distinguished micro-agility and macro-agility strategies, as well as demand-side and supply-side agilities for firms that deal with different CODPs. Several propositions and a conceptual framework have been developed accordingly to formalize the digitalization contribution to demand/supply-side micro/macro agility in DTO, MTO, and STO.

The theoretical contribution of this paper is 2-fold: First, it defines agility at micro and macro levels for the demand-side and supply-side of the order fulfillment process for different CODPs, which reflect different levels of uncertainty. While macro agility senses and responds to major trends and their uncertainties in the demand and/or supply (named macro uncertainty), micro agility focuses on unpredictable changes and uncertainties, occurring to individual orders or deliveries (named micro agility). This elaborates the concept of agility and deepens the literature view on specific features of agility in terms of dynamic flexibility, dynamic speed, and dynamic sensing (Oliva et al. 2019). Flexibility, speed, and sensing capabilities are identified and differentiated in the demand and supply sides of the order fulfillment process in DTO, MTO, and STO systems—aligned with the research call

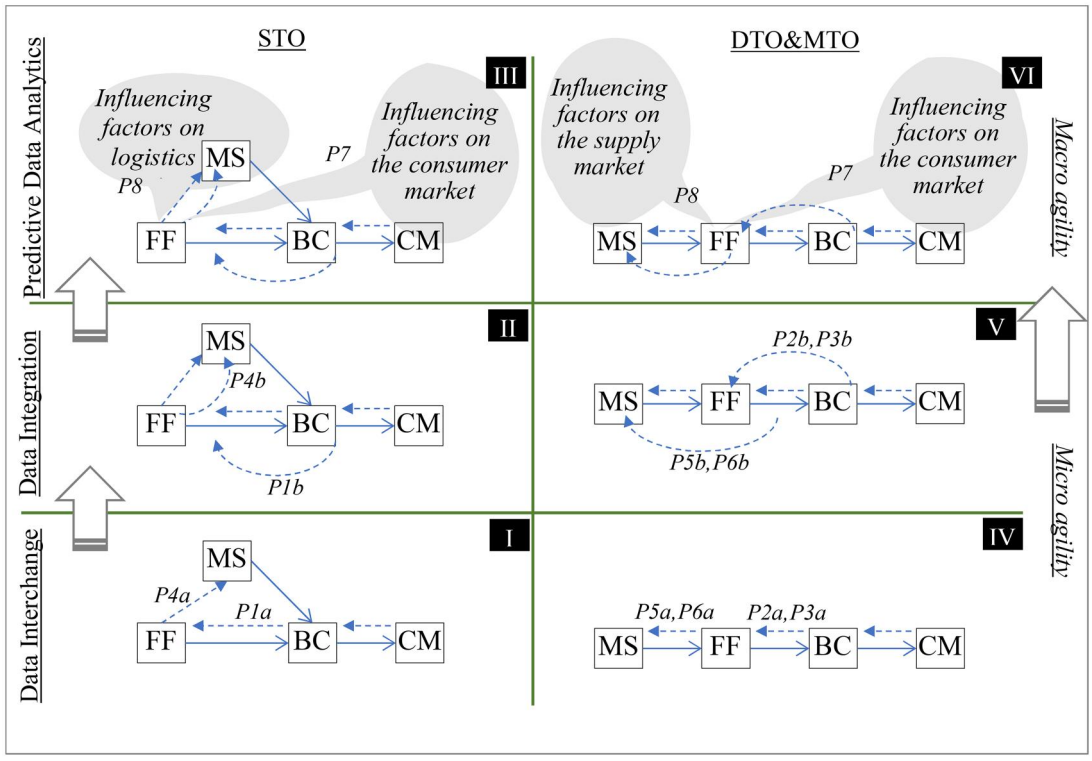

Figure 4. Digitalization contribution to *demand-side* and *supply-side micro agility* and *macro agility* in DTO, MTO, and STO systems (research propositions are shown by italic *P*). BC: business customer; CM: consumer; FF: focal firm; MS: material supplier. ⟶: Physical flow; - -▸: data interchange; ⌒▸: data integration (providing direct access).

of Sharma et al. (2021). This paper also discusses how they are different in responding to micro and macro uncertainties—as called for by Ramos, Patrucco, and Chavez (2023).

Second, digitalization applications and implications are explored for various types of agility. The outcomes of this research re-emphasize the positive impact of digitalization on the firm's design/innovation (Scuotto et al. 2017), as well as on the data interchange with its customers/suppliers (Centobelli, Cerchione, and Ertz 2020), as the main enabler of micro agility in both demand and supply sides. More specifically, the results show how digitalization supports transparency, collaboration, flexibility, and order commitment, widely recognized as key driving forces for agility (Khan et al. 2009). Micro agility also drives digitalization to be expanded more and above data interchange (Monahan and Hu 2015). It requires integrated information systems and databases to be shared among relevant parties in the order fulfillment process (Yang 2014), which elaborates Gligor, Holcomb, and Feizabadi (2016) view to process integration as the main enabler of agility. For macro agility, more advanced data and digital technologies, such as business intelligence and BDA support the firm in finding more about the factors that affect demand and supply markets and their emerging patterns and trends. This enhances the market sensing models recommended by Aslam et al. (2018). Advanced digitalization contributions also support Chakravarty, Grewal, and Sambamurthy (2013) notion of entrepreneurial agility to anticipate and seize market opportunities proactively, modify the firm's positioning and strategies, and organize new business approaches to gain early advantages in changing conditions.

Overall, this research shows that digitalization expansion from data interchange (one-to-one connections) to data integration (many-to-many connections), and towards business intelligence and predictive BDA (as shown in the upward moves in Figure 4) is necessary to support the firm's agility at the micro level and enhance it to the macro level, in the demand and supply sides of the business. The transition of digitalization from data interchange to data integration, BDA, and predictive analytics enhances the Barlette and Baillette (2022) and Sambamurthy, Bharadwaj, and Grover (2003) models on the inter-connections among IT competency, digital options, and agility, by specifying the wider range and implications of digitalization and agility. This also extends the idea of Bonnet and Westerman (2021) that adapting digital technology to mechanize old processes is not enough, and business processes may need structural and functional changes to benefit from digitalization.

This research has been limited to the impact of digitalization on agility. Future research can investigate other aspects of digitalization and agility relationships. Recent studies by Ciampi et al. (2022), Giacosa, Culasso, and Crocco (2022), and Wohlleber et al. (2024) suggest further research on the possible contribution of agility to digitalization. Agility is recommended as a critical dynamic capability for digital transformation (Moi and Cabiddu 2021; Warner and Wäger 2019) which also encourages further digital investment (Nwankpa and Merhout 2020). Different levels of

digitalization support for micro and macro agility in different customization conditions can be leveraged by future studies on the reverse relationships between digitalization and agility.

The explorative, qualitative case study approach of this research has limitations that future research can overcome. The research data are from three clothing manufacturers. Although the cases are selected carefully to reflect the heterogeneity of the research subject, the paper's outcomes, to be generalizable, need to be tested by more cases in broader stages of the supply chain and in other industries, or possibly by large-scale survey data. Moreover, future research may focus more on advanced and emerging technologies in digitalization, and measure the specific impacts of Big Data, Internet-of-Things, AI, and business intelligence tools on agility more explicitly.

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Appendix A.

Representative quotes, extracted from the research data according to the coding keywords.

Coding keyword clusters	Illustrative quote	Relevant theme
Customer expect(ation)/need/ want, order qualifier/ winner.	*Alpha:* "Customer negotiates on every element of the price and pushes for further and further discount, at the same time customer expects the order to be ready in a quite short time window […] the market is competitive, and we do all that we can not to disappoint our customers." "Quality control should be an attached part of our business."	B, P P B,P B,P B,P
	Alpha: "Not all customers know or are clear about what they want."	
	Beta: "We are really good in design – I mean creative sportswear design […] the loyalty of our customers is good proof of it. We focus on quality and we give our customers the uniqueness that they are looking for." "Obviously we do not take our success and customers for granted. We know that we need to work hard for each order and make it ready on time. Time is crucial for our business." "The market is getting competitive, and not all customers want to pay a high price [for the premium quality]. This always reminds us about monitoring our costs too."	
	Beta: "Time is crucial for our customers, and sometimes even a one or two-day delay is not acceptable – the club places its order very late or changes it at the last minute, and wants it for its next weekend match!"	
	Gamma: "Wholesalers are reluctant to keep much stock in all their different locations, [instead] they expect us to send them what they need to their desired locations, at short notice." "The problem is that the customer changes the order (for example the delivery location or time) after the delivery lorry has left our warehouse." "We tried to manage part of the problem by keeping extra inventory and making sure everything is available at any time […]"	
Demand (pattern, trend, behaviour)	*Alpha:* "It is almost impossible to guess what the next customer order is […] customers and their tastes constantly change […] all that I can see over recent years is that we have not changed our operations capacity that much, which indicates that the overall demand has more or less remained at the same level."	B B,P B
	Beta: "Our market demand is extremely diverse, and one size [design] does not fit all orders." "At a very general level, we know what a gym or sports club typically demands, but this does not help that much. The devil is in the detail, where for each order we need to spend hours, days or even weeks to agree on all details."	
	Gamma: "I would say we've enjoyed a stable demand over the years, but the situation is changing."	
Customization, variety, options, choices, fit to, design(ed) to/for, made to, shipped to.	*Alpha:* "The base design for all our products is the same, but the features can be, of course, fitted to what the customer asks for." "We usually have three [quality] grades of fabric for our products: premium, high, and basic."	B B B
	Beta: "Our customers are special, and their orders are special too […] each order [i.e. product] is especially (entirely or sometimes partially), designed for them […] this is not very new, all sports clubs do the same thing."	B
	Gamma: "Our product range has remained the same for the last many years […] there was not much effort to change the product design as it seems our target is happy with our products, as long as we keep the price down." "We need to keep the [product] quality consistent, and make sure it is available, whenever and wherever our wholesalers [(i.e. our customers)] want the product to be shipped to."	
	Gamma: "We try to keep our products affordable for low-income families … . [to do this] we need to focus on quantity and very few colors, only white for some items … , and we have never had any major change in them."	
Performance, quality, delivery	*Alpha:* "I can't say we've never had a dispute on product quality. I would say more than rarely […] some customers were quite picky and asked for full product quality inspection report, or they did the inspection at our cost!" "To reduce inspections on delivered items, we tried to be proactive and monitor the product/process quality within our production facility. It costs us and the process is sometimes very lengthy, but at least we faced fewer complaints."	P P P
	Beta: "When we rush it, due to short expected delivery lead-time, we end up having problems with the product quality – not usually a major one though (say minor shade variation or missing a stitch), but they are not usually tolerated by our customers."	
	Gamma: "The delivery companies that we work with have some ups and downs which may cause delays in deliveries."	
Supply/supplier	*Alpha:* "Our suppliers are not always supportive; there were occasions in some important business deals that a supplier was really a pain in the neck – delays after delays […] to avoid such headaches, we hold extra stock of many of our purchasing items."	P P
	Gamma: "Yes, we see our delivery company as the main service supplier, which should be monitored constantly, as they caused some problems for the order fulfillment process before."	
Agility, quick response, quick action, flexibility	*Alpha:* "Yes, what you call agility is implemented in our facility, by keeping more stock, extra working shifts, extra quality control, and extra meetings with the customer […] but no one in our company disagrees that meeting what the customer wants, and meeting his changing requirements is not going to be cheap […] these, very frankly, put us in a financially difficult position."	P B, P B, P B, P
	Beta: "We are flexible for a wide range of designs, but to respond quickly and	

(*continued*)

Continued.

Coding keyword clusters	Illustrative quote	Relevant theme
	properly we need to understand what the customer is exactly looking for."	
	Gamma: "More stock supports our quick action."	
Information/data flow, workflow, ordering system, order management system, order fulfillment system	*Alpha:* "The whole process of receiving, agreeing on, producing, preparing, and shipping an order was very much manual, as you can see in some of our old internal process documentation." "Such a manual workflow was also reviewed and updated manually but not very frequently – you can see the revision dates in the documentation too." "Most of our products and sales records can still be found in our physical archive." "At some point, around three years ago, we really reached the point that the manual systems could not work for us. We had to take the digital approach or lose the whole business." "The IT team expanded quickly and they could transfer all our product profiles online, make the links with customers electronically, and most of the paperwork digital." "We managed to have a capable extranet to embed a semi-EDI system, which takes care of orders, deliveries, and payments."	D D F D
	Beta: "Our previous sales system had all our products online, but the whole process of order management [i.e. customer order fulfillment] was manual, with several face-to-face meetings with the customer." "Advanced technologies such as virtual reality were then introduced to facilitate the order receiving stage […] to maximize the benefit of technology, we went much further and redesigned the whole sales and order management system in such a way that customers can be engaged further […] the new workflow, when tested, showed a significant improvement – 14 out of 30 orders were made totally online and only five of them went through a couple of short meetings with the customer." "The customer can amend its order *via* the extranet platform, which transfers the change-data to us very quickly." "Financial transactions with customers are done through a new electronic system, as well."	
	Beta: "The plan is to expand and improve the online customer ordering system to make it more reliable, convenient, and accurate."	
	Gamma: "Our order management and delivery system for many years worked based on simple MS-Word order placement and MS-Excel invoice forms that we asked our customers to complete to communicate their orders with us. Further communications, including complaints, could be done *via* email." "The physical flows of the orders were monitored by a simple barcode system […] all our products have barcodes at individual, box, and pallet (if applicable) levels."	
Digitalization, e-commerce, online, website	*Alpha:* "Our digital product catalog was initially a great move to share our product profile with a wider range of audience."	D D
	Beta: "It is good to have a website, but it barely finds a new customer. Our main accounts have remained almost the same for the last 5–10 years … "	P, D
	Gamma: "We transferred the old-fashioned file/email-based system to an online/extranet-based system to make our communications with the customer much more efficient." "This made all our communications organized *via* electronic channels." "Our plan for the longer-term was to link the physical moves of the order to the online ordering system, and we learned about and used RFID for that purpose." "RFID gave us 100% visibility of our order/stock status, while it was coupled with the satnav system used by the delivery lorries." "We finally could have the agreement of our wholesalers to share their inventory data with us, so we can be more pro-active."	
Advanced information/digital technology, Big Data, virtual reality, augmented reality, business intelligence.	*Alpha:* "Our team has lots of ideas for the near future […] we see numerous opportunities for technologies such as virtual reality to be added to our online sales and big data can help us find out more about other industries or businesses, like fashion, which may affect our customer orders, so in future, we can learn more about our customer preferences and make ourselves ready for them […] our production team is also working with smart sensors and more integrated production-quality control systems to have more visibility of the whole system […] the plan is to expand such integration to our key suppliers too."	F F F
	Beta: "Big data can find what is really happening in the market – not just the sales figures, but probably more analysis about consumer behavior and many other unknowns."	
	Gamma: "Big data is everywhere these days, and we are keen to use it to find more about the market and trends." "I believe big data, received from our wholesalers can help us forecast the future demand too."	

B: business operations model; P: problems/solutions; D: data management/digital transformation plans; F: future digitalization and enhanced agility.