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# Adapting sales and operations planning to dynamic and complex supply chains

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## Abstract

Traditional supply chain planning (SCP) processes are generally effective in stable business environments where demand and supply are predictable and reliable. However, firms are no longer operating within static systems. Instead, they are embedded in dynamic and complex supply chains that challenge the effectiveness of traditional SCP processes, necessitating their adaptation. In this context, this paper focuses on sales and operations planning (S&OP), representing an SCP process on a tactical level. The paper introduces a novel framework for adapting the S&OP process to dynamic and complex supply chains. An empirical research approach is employed to achieve this goal, embracing a multiple case study of three firms operating in different contexts. The research leverages Complex Adaptive Systems (CAS) theory as a theoretical lens to embrace the characteristics of dynamic and complex supply chains of the three firms, representing the first application of this theory within the domain of S&OP research. The proposed framework encompasses five propositions designed to advance the theoretical understanding of S&OP, thereby contributing to the development of a unified S&OP theory. Moreover, the framework provides practical guidance for managers seeking to adapt their firm's S&OP process towards dynamic and complex supply chains.

**Keywords** Supply chain planning · Tactical planning · S&OP · Risk management · Complex adaptive systems · Sales and operations execution

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## 1 Introduction

### 1.1 Problem background and research motivation

Traditional supply chain planning (SCP) typically relies on “the assumption that the future would be much like the past” (Christopher and Holweg 2017, p. 3). Under this assumption, a supply chain can be considered a static system that can be separated into different delimited and solvable parts with stable and linear relationships between various supply chain members (Nilsson and Gammelgaard 2012; Nair and Reed-Tsochas 2019; Wieland 2021). Herein, SCP is typically conducted by using historical data (Christopher and Holweg 2017; Browning et al. 2023) as demand can be predicted, supply is reliable, and capacity, labour availability, and distribution channels are expected to be fixed constants (Sodhi and Tang 2021). This enables a focus on realising an effective and efficient supply chain management, characterised by achieving the highest possible grade of controllability and optimality (Wieland 2021). However, the assumption of a supply chain as a static system is questioned as it ignores its adaptive nature (Nair and Reed-Tsochas 2019; Wieland et al. 2023).

Instead, a growing number of researchers and managers acknowledge that a supply chain nowadays is “dynamic, complex, and difficult to predict and control” (Carter et al. 2015, p. 90). Recent years have provided several real-world examples of this emerging foundational premise. For instance, there have been events with huge or even systemic impacts on supply chains and their designs, such as the Covid-19 pandemic, geopolitical developments, or natural catastrophes (Alexander et al. 2022; Bednarski et al. 2023; Browning et al. 2023; Wieland et al. 2023). As a consequence, an effective SCP is challenged when firms are no longer part of a static system with a stable and reliable set of actors and behaviours but, instead, a dynamic and complex system. Thus, traditional SCP and its underlying processes have become increasingly inadequate (Browning et al. 2023; Kalla et al. 2023).

This reflects the reality of sales and operations planning (S&OP) (Kalla et al. 2025), which has evolved into one of the most prominent processes for SCP on a tactical level (Jonsson and Holmström 2016; Kreuter et al. 2022). S&OP aims to reconcile demand and supply through a formal and sequential process embracing planning steps and joint decision-making meetings (Thomé et al. 2012; Laari et al. 2023). The theoretical understanding of the S&OP process is mainly based on studies assuming that the supply chain is a static system with independent firms being part of it (Kristensen and Jonsson 2018; Jonsson et al. 2021). However, this underlying assumption has contributed to an ongoing gap between the theoretical understanding on the one hand and practitioner needs on the other. For instance, various studies provide models and frameworks supporting firms in running an S&OP process that can lead to increased organisational performance, resulting in operations-related, finance-related, and supply chain-related benefits (Thomé et al. 2014; Kreuter et al.

2022). But, at the same time, firms are struggling to realise these benefits in real-world settings (Kristensen and Jonsson 2018; Kreuter et al. 2021). Consequently, the theoretical understanding of the S&OP process needs to be advanced (Kreuter et al. 2022) by embracing practical implications regarding S&OP as an SCP process in dynamic and complex supply chains. This leads to an important step towards the development of a unifying and more comprehensive S&OP theory.

In this regard, researchers and managers need to recognize that the S&OP process was not originally designed to be applied in a system that “is under continuous change” (Jonsson et al. 2021, p. 555). Consequently, it requires adaptation to function effectively in such settings (Kristensen and Jonsson 2018; Kreuter et al. 2022). Preliminary academic studies and practitioner reports indicate that firms have begun adapting their S&OP process to deviate from traditional approaches (Dittfeld et al. 2021; Lawless 2023; Lapide 2024; Kalla et al. 2025). However, knowledge of specific characteristics associated with dynamic and complex supply chains remains fragmented and limited. This gap has encouraged practitioners to adapt their traditional firm’s S&OP process to address this current challenge without robust scientific evidence.

## 1.2 Research question and goal

This scenario leads to the following research question: How can the S&OP process be adapted to dynamic and complex supply chains? To investigate this research question, Complex Adaptive Systems (CAS) theory is employed as a theoretical lens. Here, the supply chain is considered a CAS, i.e., a system that co-evolves as a result from its internal mechanisms and environment (Carter et al. 2015; Nair and Reed-Tsochas 2019).

Against this backdrop, the goal of the paper is to develop a framework for adapting the S&OP process to dynamic and complex supply chains. Specifically, this paper aims to advance the ongoing theory development cycle (Meredith 1993) within the S&OP domain, as called by Kreuter et al. (2022), by enriching the theoretical understanding of S&OP in such a setting and introducing CAS theory as a novel lens for S&OP research. Additionally, the proposed framework intends to guide managers in adapting their firm’s S&OP process towards dynamic and complex supply chains. Given the scarcity of S&OP literature on this emerging topic (Kreuter et al. 2022; Kalla et al. 2025), this research adopts an empirical approach. A multiple case study methodology involving three firms is employed. Through the lens of CAS theory, the study analyses how these firms have adapted their S&OP processes to dynamic and complex supply chains. Both within and cross-case analyses are conducted to identify patterns and derive a generalised solution.

## 1.3 Paper’s structure

The paper is structured as follows: Section two offers the theoretical background; section three describes the methodological approach adopted; section four presents the results, which are further discussed in section five; and section six provides the conclusions, research limitations, and suggestions for future investigations.

## 2 Theoretical background

### 2.1 Introduction to supply chain planning and sales and operations planning

SCP refers to coordinating and synchronising demand-facing and supply-facing activities to create value in the supply chain (Oliva and Watson 2011; Jonsson and Holmström 2016). It takes place on a strategic, tactical, and operational level (Van Landeghem and Vanmaele 2002; Oliva and Watson 2011), traditionally by projecting the future based on historical data (Christopher and Holweg 2017). Strategic SCP is concerned with the design and structure of a supply chain and, thus, has long-term effects. In contrast, operational SCP refers to the specification of day-to-day activities for immediate execution (Fleischmann et al. 2015). Tactical SCP serves as an intermediate and translates strategic plans into feasible mid-term plans of regular operations (Fleischmann et al. 2015; Pereira et al. 2020). It aims to balance demand and supply by contributing to improved coordination within the firm and the supply chain (Steinrücke and Jahr 2012; Bajgirani et al. 2016; Shurrab et al. 2022). In recent years, S&OP has evolved into a tactical SCP process with a pivotal role in ensuring this balance (Jonsson et al. 2021; Shurrab et al. 2022).

S&OP “unites different business plans into one integrated set of plans” (Thomé et al. 2012, p. 1) and targets a horizontal alignment across different functional areas and a vertical alignment by bridging between strategic and operational SCP (Kristensen and Jonsson 2018; Seeling et al. 2022). Traditionally, S&OP is conducted through a formal business process with sequential steps for data gathering, demand planning, supply planning, a pre-meeting, and an executive meeting (Wallace and Stahl 2008; Kreuter et al. 2021). Apart from its steps, the S&OP process can be further explained through three setup parameters, i.e., planning frequency (how often is the process conducted?), planning horizon (what is the range of time a plan covers the future?), and planning object (what is the plan’s level of detail?) (Ivert et al. 2015; Kristensen and Jonsson 2018). Accordingly, the traditional S&OP process is conducted monthly (planning frequency), covers a tactical planning horizon that can range between four and 24 months (planning horizon), and aggregates on a product group or product family level (planning object) (e.g., Wagner et al. 2014; Kristensen and Jonsson 2018), see Fig. 1. If implemented and conducted properly, the S&OP process can yield a wide variety of benefits, such as higher forecast accuracy, lower inventory,

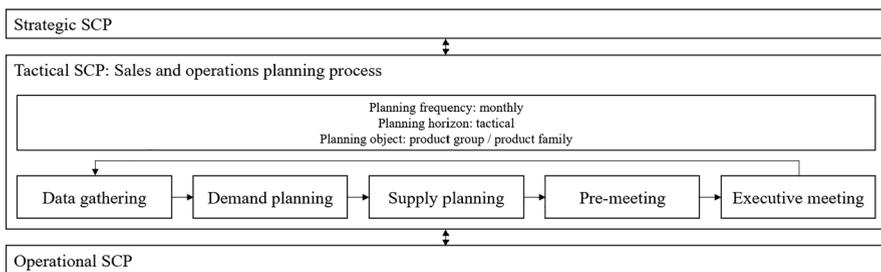


Fig. 1 The traditional S&OP as a tactical SCP process

optimised capacity utilisations, or higher profit margins (Thomé et al. 2012; Wagner et al. 2014; Pereira et al. 2020; Kreuter et al. 2021).

Due to their desired benefits, the S&OP process has enjoyed high interest, reflected in a growing number of academic publications and industrial implementations (Kristensen and Jonsson 2018; Kreuter et al. 2022). However, it can still be considered an emerging SCP process, characterised by a highly fragmented knowledge base (Kreuter et al. 2022). Furthermore, most academic literature fails to support practitioners in solving their current S&OP problems (Jonsson et al. 2021; Kalla et al. 2025). As a result, there is an ongoing gap between theoretical knowledge and practitioner needs (Jonsson and Holmström 2016; Stentoft et al. 2020; Kreuter et al. 2021), highlighting the lack of a comprehensive theoretical understanding of the S&OP process. In this regard, taking additional steps toward evolving the theory development cycle is important to develop a unifying theory for S&OP (Kreuter et al. 2022).

The theory development cycle from Meredith et al. (1989) and Meredith (1993) embraces description, explanation, and testing. Descriptions of the S&OP process have begun with practitioner reports and textbooks (e.g., Lapidé 2005; Wallace and Stahl 2008), building the basis for the first academic models and frameworks (Kreuter et al. 2022; Neto et al. 2024), such as the maturity model developed by Grimson and Pyke (2007). This model has been used for being explained through further models and frameworks (e.g., Thomé et al. 2012; Danese et al. 2018), as well as for describing and explaining new aspects of S&OP, such as coordination mechanisms (Tuomikangas and Kaipia 2014) or performance measurement (Hulthén et al. 2016). The models and frameworks developed provide important and valuable descriptions and explanations of the value of the S&OP process and, thus, contribute significantly to an increased theoretical understanding of S&OP (Kreuter et al. 2022). However, most of the corresponding studies do not sufficiently address how the S&OP process can work effectively when applied in dynamic and complex supply chains (Jonsson et al. 2021; Kalla et al. 2025). This is considered necessary to advance further the theoretical understanding of the S&OP process, as well as to address practitioner needs, making an important step towards filling this theory-industry gap.

## 2.2 Sales and operations planning in dynamic and complex supply chains

A dynamic and complex supply chain can be considered a CAS (Carter et al. 2015; Nair and Reed-Tsochas 2019; Wieland and Durach 2021). A CAS is a system that co-evolves because of the interplay between its internal mechanisms and its environment (Choi et al. 2001). More precisely, the co-evolution embraces a quasi-equilibrium and state change, non-linear changes, and a non-random future as a result of changes in the internal mechanisms and the environment. As the S&OP process needs to be adapted towards being prepared for any co-evolution in general, this research focuses on the system's internal mechanisms and environment. Table 1 illustrates a CAS's internal mechanisms-related and environment-related constructs and relates them to the context of supply chains, inspired by Choi et al. (2001) and Carter et al. (2015).

For working effectively in a dynamic and complex supply chain that entails the constructs of a CAS, the traditional S&OP process is no longer sufficient and, thus, needs to be adapted (Kristensen and Jonsson 2018; Jonsson et al. 2021; Kalla et

**Table 1** Constructs of a CAS and their relations to supply chains

| CAS constructs                  | Description   | Relation to supply chains  |
|---------------------------------|---|--|
| <i>Internal mechanisms</i>      |   |  |
| Agents                          | Agents refer to entities that together build up a complex system and that are able to make meaningful decisions | Individual firms that work together, e.g., suppliers, customers, and the own firm including its different functional areas   |
| Self-organization and emergence | Agents make simultaneous and parallel decisions; no agent organises or controls the entire system               | Firms that are part of the supply chain can make decisions by following their own rules and norms; for example, the supplier may aim to be flexible, whereas the manufacturer may aim to be efficient. The same can happen within a firm and its internal functional areas (e.g., sales versus operations) |
| Connectivity                    | Interrelationships exist between agents   | Firms may be connected, although they manufacture different products for different customers. For example, a consumer electronics manufacturer may compete with a car manufacturer for the same resources  |
| Dimensionality                  | Dimensionality is related to the degree of freedom agents have when making decisions                            | The more a firm needs to consider external factors in their decision-making, the less free they are to make independent decisions, e.g., a pharmaceutical manufacturer needs to adjust its production to a wide range of national laws and regulations   |
| <i>Environment</i>              |   |  |
| Dynamism                        | Changes can occur and can have system-wide consequences   | Firms are confronted with uncertainties that impact their own firm, their supply chain, and beyond. For example, the Covid-19 pandemic led to changes in customer demand patterns, resulting in stock-outs   |
| Rugged landscape                | A rugged landscape refers to the difficulty of finding the best possible solution for a problem                 | The more suppliers a firm has, the more products it offers, the more regions it is operating in, the more competitive the market, etc., the more difficult it is for the firm to identify the best supply chain-related decision   |

al. 2025). However, literature on dealing with this need is still scarce. Among the few existing studies, most pay attention to following a more reactive approach. For instance, authors highlight the need to implement an additional event-driven S&OP meeting, sometimes also called ad-hoc or crisis meeting (e.g., Wagner et al. 2014; Danese et al. 2018; Dittfeld et al. 2021). Such a meeting takes place if an unexpected change in the supply chain occurs and an immediate response is required, for instance, after a demand spike, a supplier bankruptcy, or a machine breakdown. Recent articles build upon this idea and emphasise the need for establishing a stronger vertical alignment by building a closer linkage between the S&OP process and operational SCP processes, e.g., through the implementation of an additional quick response planning process (Bower 2018; Lapide 2022) or the emerging sales and operations execution (S&OE) process (Hainey 2022; Dombroski 2024; Kalla et al. 2025).

While this linkage can be highly valuable or even necessary to deliver the initial S&OP plan even after the exposure to unexpected changes, the S&OP process should not lose its proactive nature (Tuomikangas and Kaipia 2014; Jonsson et al. 2021). Accordingly, an S&OP adaptation must also enable proactivity when facing a high degree of dynamism. In this regard, integrating supply chain risk management

(SCRM) activities into the S&OP process has been recognised as a valuable solution for an adaptation in this regard (Noroozi and Wikner 2017; Kristensen and Jonsson 2018; Kreuter et al. 2022). It is based on the consensus that uncertainties within the firm, the supply chain, and beyond are both antecedents and drivers of risks (Thomé et al. 2016). Therefore, SCRM has emerged as a promising approach for managing dynamism in the supply chain by proactively and reactively managing or avoiding risks (Roscoe et al. 2020). Despite the consensus on the potential of this integration, research on this topic is still in its infancy.

Dittfeld et al. (2021) conducted a multiple case study with seven firms and investigated SCRM activities within their S&OP processes. According to the results, risk identification can be integrated into the demand and supply planning steps of the S&OP process, whereas risk treatment can be conducted within the pre-meeting or the executive meeting steps. In contrast, the integration of risk assessment and risk monitoring is not considered equally necessary. Additionally, a reactive crisis meeting can be scheduled for immediate response purposes. Recently, Kalla et al. (2025) built upon Dittfeld et al. (2021) and developed a framework highlighting integration possibilities of SCRM activities into the S&OP process. Their study is based on insights from both literature and expert interviews. It investigates the topic from a broader theoretical lens. First, risk identification does not have to be integrated into the S&OP process. Second, risks can be assessed within the demand and supply planning steps. Third, decisions on how to treat risks are made within the cross-functional pre-meeting and cross-hierarchical executive meeting based on proposals developed before the meetings. Fourth, risk monitoring can be conducted in any S&OP process step or through an additional process run in parallel. This additional process is characterised by a higher planning frequency and lower planning horizon than S&OP and can also be used for risk treatment purposes.

The studies above provide important contributions to an advanced theoretical understanding of adapting the S&OP process to dynamic and complex supply chains. However, they lack an explanation of which CAS constructs affect the design of an adapted S&OP process, which is relevant for taking steps toward developing a unifying S&OP theory and filling the current theory–practice gap in SCP and S&OP research. Therefore, this paper aims to investigate this topic further. It, therefore, follows an empirical research approach, which is described next.

### 3 Research methodology

#### 3.1 Research design

For this research, a case methodology was applied. A case study is conducted to investigate phenomena in real-world settings (Yin 2013) and was considered adequate for this research for different reasons: First, it is particularly applicable for investigating contemporary phenomena (Meredith 1998). In fact, the topic investigated in this research enjoys a growing interest in academia and industry (Dittfeld et al. 2021; Lapidé 2022; Kalla et al. 2023; Lawless 2023). However, the body of knowledge on adapting the S&OP process to dynamic and complex supply chains is still scarce,

which made a systematic literature review inadequate. Additionally, a case study typically addresses “how” questions (Yin 2013) and thereby fits adequately to the research question of this paper. At the same time, it enables an iterative, exploratory, in-depth investigation, which is impossible through other empirical approaches, such as surveys. Moreover, analysing the theoretical constructs (from CAS theory, see Table 1) requires a deep contextual understanding (Yin 2013). Quantitative approaches would not suffice to capture a supply chain's dynamic and complex nature as a CAS (Choi et al. 2001). Finally, a case study is suitable for developing models and frameworks with industrial relevance (e.g., Danese et al. 2018; Seeling et al. 2022). A multiple case study approach was chosen as it can overcome the weakness of a single one and its limit on generalising results and conclusions (Voss et al. 2002).

The research design embraces selecting adequate cases, collecting required data, and analysing the data to address the research goal (Yin 2013). The approaches for these three research steps conducted herein are presented next.

### 3.2 Case selection

Three firms were selected for the case study research. They all have an established S&OP process in place and adapted it, aiming for an effective application for tactical SCP purposes in dynamic and complex supply chains. The firms were selected based on their contexts to ensure a diverse set. Accordingly, based on the suggestion of Kreuter et al. (2022), the three firms differ in terms of sector and industry, firm size, and operations strategy. For defining the sector and industry, the Global Industry Classification Standard (S&P Global and MSCI 2018) was followed. For determining the firm size, Gartner's (2023) classification was applied, which distinguishes between small-sized (less than 100 employees and an annual revenue of less than 50 million US dollars), mid-sized (between 100 and 999 employees and an annual revenue of more than 50 million and less than 1 billion US dollars), and large-sized firms (more than 1,000 employees and an annual revenue of more than 1 billion US dollars). The operations strategy distinguishes between different common approaches for procurement (e.g., purchase-to-stock, purchase-to-order, based on Ni 2019) or manufacturing (e.g., make-to-stock, make-to-order, engineer-to-order, based on Kreuter et al. 2022). The three firms are introduced next. To ensure anonymity and confidentiality, the actual firm names were replaced by codes (Firms A, B, and C).

*Firm A* Firm A is a mid-to-large-sized (mid-sized in terms of revenue and large-sized in terms of employees) multinational manufacturing firm with its headquarters in Europe. It is part of a global supply chain with suppliers and customers worldwide. It operates in a highly competitive market within the health care sector, producing and offering a wide range of products for medical research and clinical application, and it is classifiable to both discrete manufacturing and the process industry. The firm follows a make-to-stock strategy as a permanent availability of the products is necessary to enable immediate patient treatment. However, it faces high uncertainties due to complex medical developments worldwide, difficulties in predicting the demand for innovative new products, and frequently changing and globally diverse regulatory requirements.

*Firm B* Firm B is a large-sized multinational manufacturer in the industrials sector with its headquarters in Europe and operations worldwide with suppliers and customers located in various continents and countries. The firm produces specialised devices and equipment in a highly regulated market, applying a make-to-order strategy. Furthermore, the market for raw materials and other resources is highly competitive, making it difficult to ensure their availability at the right time. The customer-specific preferences are hard to predict, challenging effective demand planning. Sometimes, these preferences include parts that need to be sourced exclusively, but rarely, implying additional supply uncertainty.

*Firm C* Firm C is a mid-sized distributor of a wide range of consumer staple products for pets and other animals, operating in one dedicated country in Latin America. It follows a purchase-to-stock strategy, with goods being sourced from very powerful suppliers and kept on stock until delivered to the final customer (mainly retailers of pet supplies). The supply and demand of these goods strongly depend on various issues that are hard to predict, such as health-related developments on humans (e.g., the Covid-19 pandemic) and animals (e.g., flu), political (e.g., labour-related legislations) and economic developments (e.g., inflation) in the dedicated country.

### 3.3 Data collection

Various data collection methods were applied to serve triangulation and, thus, to provide substantiation of the collected insights and developed outcomes (Eisenhardt 1989; Voss et al. 2002; Barratt et al. 2011). Semi-structured interviews were conducted with the firm's main S&OP actors (see Table 2), following the guidelines of Myers and Newman (2007) for interview preparation, execution, and post-processing. The interview questions were structured based on understanding the current adapted S&OP process and further adaptation plans for the future to relate them later to the constructs derived from CAS theory (Choi et al. 2001). The interviews were recorded (except for one firm due to organizational policies), transcribed, and coded using thematic analysis (Braun and Clarke 2006). The coding process followed a hybrid approach, combining deductive coding based on the CAS constructs and inductive coding to capture emergent themes from the data (Miles and Hubermann 1994). This ensured the identification of patterns in how firms have adapted and further plan to adapt their S&OP process. Direct quotes of Firm A and C representatives were used in the findings section of this paper whenever they contributed to a better understanding (Rockmann and Vough 2023).

**Table 2** Interview details

| Firm | S&OP representatives involved in the interviews   | Average length of the interviews (h) |
|------|---|--------------------------------------|
| A    | S&OP team; sales; marketing; production; purchasing; quality management; and research and development | 0:40                                 |
| B    | S&OP team; sales; operations; purchasing; finance; and risk management                                | 0:50                                 |
| C    | S&OP team; executive board; sales; commercial intelligence; and purchasing                            | 1:15                                 |

Field visits were conducted to all three firm's operational plants to complement data collected from the interviews. The visits were enriched by applying additional methods, such as shadowing (McDonald and Simpson 2014) or attending S&OP meetings, aided by observation guidelines (Seeling et al. 2021). Additionally, the researchers accessed internal reports, historical S&OP data, and documentation on past risk treatment strategies, which were analysed using qualitative content analysis (Mayring 2000). Moreover, regular feedback loops with all three firms were an essential part of the case study, realised through unstructured interviews with S&OP team representatives of each firm. All interview transcripts and notes made are collected using a case study protocol. Based on this, the firm's as-is and to-be states were documented textually and graphically. Workshops were conducted between the researchers and firm representatives. The research findings from the three firms were synthesised into a framework, which was later evaluated through additional semi-structured interviews conducted with the S&OP managers and at least one additional representative of each studied firm.

### 3.4 Data analysis

The multiple case study followed a sequential two-step approach, structured according to a within-case and a cross-case analysis (Eisenhardt 1989, 2021). First, in the within-case analysis, the firms were observed regarding how and why they have adapted their S&OP to dynamic and complex supply chains, enabling the identification and analysis of the firm's current as-is processes. Due to the fact that the firms were planning and implementing further adaptations, these plans for future to-be processes were included in the observation as well. For this step, the interview transcripts, internal documents and reports, notes made during the field visits, feedback loops, and workshops were analysed qualitatively, following the guidelines of Mayring (2000). Herein, data was analysed through the lens of CAS theory. Second, in the cross-case analysis, the findings from the within-case analysis were analysed and generalisations beyond firm-specific findings were derived. A synthesis of the three individual analyses finally led to a framework embracing propositions to support managers in realising such an adaptation. As mentioned before, preliminary findings were shared regularly with the firms through feedback loops to ensure the correctness of the interpretations and conclusions made by the researchers and to achieve generalisability, following Schlegel et al. (2021). This procedure was repeated in all cases of disagreement or misalignment until a consensus was achieved.

According to Yin (2013), a case study can be judged by ensuring adherence to construct validity, internal validity, external validity, and reliability tests. As internal validity is only relevant in explanatory research, it was not addressed in this research. The tactics for ensuring the other three tests are mentioned before and summarised in Table 3.

**Table 3** Tactics for ensuring construct validity, external validity, and reliability in the case study research

| Test               | Tactic   |
|--------------------|--|
| Construct validity | Serving triangulation through semi-structured interviews with each firm's main S&OP actors, field visits (complemented by shadowing and meeting attendance), and access to internal reports, historical S&OP data, and corporate documentations<br>Regular feedback loops and workshops with representatives from each firm's S&OP teams |
| External validity  | Multiple case study approach to overcome the weakness of a single one and its limit on generalising results and conclusions<br>Application of CAS theory as a theoretical lens   |
| Reliability        | Use of a case study protocol, including interview transcripts and notes made during the field visits, feedback loops, and workshops  |

## 4 Findings

### 4.1 Within-case analysis

The within-case analysis is based on how the three case firms have adapted and further plan to adapt their S&OP processes (in terms of steps and setup parameters) to dynamic and complex supply chains. It is structured according to the three firms that all follow the same steps of the S&OP process, i.e., demand planning, supply planning, pre-meeting, and executive meeting (see Fig. 1). The analysis focuses not on the overall S&OP process but on the adaptations in particular.

#### 4.1.1 Firm A

Firm A has seven S&OP processes, one for each business unit. This parsing is because each business unit deals with different products for different customer segments and where required materials and resources are sourced from various suppliers. However, the seven processes follow the same design and setup parameters (monthly, 12-month horizon, product group level).

After a comparison and gap analysis between real-time sales data and the demand plan for this specific month, sales and marketing representatives start a reactive SCRM approach within the demand planning step. If the gap is attributed to a known risk with an ongoing risk treatment, risk monitoring takes place to evaluate the treatment's suitability and propose its adjustment if necessary. In case no known risk can be associated with the gap, demand-related risks are identified. It is complemented by a classification, leading to different possible approaches: (1) If the identified risk has strategic impacts, it is not further managed within the demand planning step but later at the executive meeting step. (2) If the risk cannot be treated by demand-sided functional areas alone but instead cross-functionally, its management is forwarded to the pre-meeting step and can be considered an early warning signal. (3) Finally, if the risk has tactical or operational impacts and can be treated by demand-sided functional areas, it is assessed in terms of its likelihood and impact. The assessment is based on human judgements as "you have the right people at the table" (S&OP manager at Firm A) with the best knowledge about Firm A's customers and market. Accordingly, their involvement enables an assessment from a volume perspective only. Once the

risk assessment is conducted, an adequate risk treatment is proposed as a final activity of the meeting. Consequently, the output of the adapted demand planning step does not only embrace the demand plan, i.e., the outcome from the traditional S&OP, but also a list of demand-related risks identified and classified, their assessment results, and proposals for a new or adjusted treatment.

When adapting its S&OP process, dynamics on the demand side have been considered more important than on the supply side. This decision is founded on two reasons: First, Firm A is a manufacturing firm in the health care sector that mainly strives for realising the demand as fulfilling or not fulfilling can affect the life or death of patients. This leads to the firm's decision to build a safety stock of three to six months for any product, making the management of supply-related dynamics with tactical impacts less relevant within S&OP. Second, Firm A has built strong and reliable relationships with key suppliers, e.g., by supply agreement contracts, leading to very few unexpected problems with suppliers. However, if an unexpected risk emerges that requires an immediate reaction, such as operational problems on the supplier side, an additional process is triggered, which is not part of Firm A's S&OP process but is closely linked to it. Accordingly, it consists of a cross-functional and cross-hierarchical meeting between purchasing and production planners and lower management representatives, in which an immediate risk treatment is decided upon. This requires strong analytical skills and sophisticated knowledge of operations and execution. Such a decision can be considered "firefighting" (production representative at Firm A). Thus, this additional process addresses a vertical alignment between S&OP and operational SCP.

Next, a cross-functional pre-meeting, embracing the S&OP manager and representatives from sales, marketing, research and development, purchasing, production, and quality management, is structured into two tasks. First, the demand planning step outputs are taken as inputs to review the risk monitoring and assessment results and to decide on the proposed new or adjusted risk treatment. Second, those risks that have not been further managed within the demand planning step are now assessed and treated. For the assessment, technological aid is essential and realised by running and analysing scenarios with both demand and supply implications. However, it is complemented by human judgements through open discussions among all involved people. These discussions are essential to ensure "that all people are informed about the events and decisions and their consequences" (marketing representative at Firm A). Based on the assessment, a decision on an adequate risk treatment is made. Finally, from an adaptation perspective, the subsequent cross-hierarchical executive meeting is only relevant when risks have strategic impacts. In this case, executives conduct a new risk assessment and decide on a risk treatment to ensure alignment with strategic SCP.

#### 4.1.2 Firm B

Firm B has decided to run five different S&OP processes, one for each business unit, as the supply chains differ strongly. On a very detailed level, this leads to minor changes among the five different S&OP processes. However, on a more general level, they follow the same procedure for being adapted to dynamic and complex supply

chains, conducted on a monthly basis with a planning horizon of 18 months, and aggregated on a product group level. It starts with a dedicated risk manager responsible for risk identification at Firm B. A list of new risks identified that should be further managed within S&OP is regularly shared with the S&OP manager. This list, thus, serves as an essential input for the different S&OP process steps.

Accordingly, the identified demand-related risks are used as input for the demand planning step. Herein, sales, marketing, and finance representatives monitor and assess these risks. The two SCRM activities are based on gathering common key performance indicators (KPIs) from an analytics module of the firm's ERP system. The KPIs are analysed according to their association with risks. This happens by reviewing whether ongoing risk treatment decisions are still suitable and how likely and impactful these risks are for the demand for Firm B's products. While gathering KPIs from the ERP system is highly important, the actual risk monitoring and assessment happen through human judgement. Afterwards, the involved representatives from sales, marketing, and finance propose an adjustment or a new approach for treating the risks. The demand plan then builds the core output of the demand planning step, enriched with risk assessment results, as well as proposed new or adjusted risk treatments.

A list of manufacturing-related and supply-related risks identified by the dedicated risk manager is used as input for the supply planning step. After a review of manufacturing-related and supply-related performance, a monitoring and assessment of corresponding risks take place, conducted by production and purchasing representatives. If the performance has decreased and can be explained through the exposure of risks identified by the dedicated risk manager, ongoing risk treatments are reviewed according to their suitability and adjusted if necessary, or the need for further management is determined. Subsequently, the risks are assessed in terms of their likelihood and impact. For this, scenarios are run and analysed within a spreadsheet. However, scenario analysis capabilities through spreadsheets are limited when the potential actions of many customers and suppliers need to be considered. Therefore, this quantitative approach to risk assessment is aided qualitatively by gathering supplier-related information through direct interaction between purchasing representatives and key suppliers. Based on the risk assessment results, possible risk treatments are proposed. The supply plan, which is the typical outcome of the traditional supply planning step, and the assessment results, as well as the proposed new or adjusted treatment, finally build the output of this step.

In the cross-functional pre-meeting, sales, marketing, production, purchasing, and finance representatives review the outcomes of the demand planning and supply planning steps. Herein, the involvement of finance plays a vital role as it embraces a financial perspective on previous risk assessments and treatment decisions for dealing with dynamic and complex supply chains. Incorporating a financial perspective can, thus, lead to adjustments to the risk assessments and treatment. The pre-meeting ends with a finalised S&OP plan as a typical output, finalised risk assessments, and agreed risk treatment. One characteristic of former pre-meetings at Firm B was that short-term risks with operational impacts were often managed here as well, such as unexpected problems on the supplier side or in the manufacturing plant. These risks were assessed and treated in the pre-meeting. However, S&OP was no longer considered

the right platform for managing these short-term risks as the regular S&OP people were not considered the right ones to manage these risks. This is why Firm B decided to implement an S&OE process. Herein, S&OP and S&OE are closely connected through continuous information exchange but considered and managed separately as two distinct SCP processes. The firm's S&OE is characterised by a higher planning frequency (weekly instead of monthly), a lower planning horizon (up to three months instead of 18 months), and a more detailed planning level (stock-keeping units (SKU) instead of product groups) than S&OP. By running an S&OE process, Firm B aims to ensure a more effective alignment between tactical and operational SCP.

#### 4.1.3 Firm C

Firm C conducts one monthly S&OP process with a planning horizon of 12 months. As it is a distributor sourcing and selling finished products, its planning focuses on an SKU level. It begins with demand planning. Herein, sales and commercial intelligence representatives first identify demand-related risks. Those with a strategic impact are forwarded to the executive meeting step, while those with a tactical and operational impact are further managed within the demand planning step. Although the value of the risk identification activity is recognised, the involved people consider it time-consuming. Second, the risks identified are then monitored and assessed in terms of their likelihood and impact. Risk monitoring and assessment activities are based on human judgements of demand-sided functional areas. In the future, representatives of these areas should be supported by those from finance. Third, new risk treatment proposals are developed for risks with tactical and operational impacts. However, the latter ones "do not really belong to S&OP" (executive at Firm C) and are outside the intended planning horizon of Firm C's S&OP process. Therefore, they should be managed in an additional process in the future. In cases of an ongoing risk treatment from previous S&OP cycles, its results are evaluated, and potential adjustments are proposed. As a result, the demand planning step ends with a demand plan complemented by risk assessment results and new or adjusted proposals for risk treatment.

The supply planning step follows a similar approach to the demand planning step. Accordingly, sales and purchasing representatives identify supply-related risks. The involvement of sales is essential in this regard. The reason is that Firm B is a distributor and follows a purchase-to-stock operations strategy, highlighting the close linkage between what is sourced from suppliers and sold to customers, or as a sales representative stated: "Our suppliers look at us as the arms of the final customers." While risks with strategic impacts are forwarded to the executive meeting step, those with tactical and operational impacts are currently considered in the supply planning step. Risk monitoring and risk assessment are conducted based on human judgements from sales and purchasing representatives and suppliers with which close and direct interaction takes place. Additionally, Firm C plans to utilise artificial intelligence (AI)-based judgements in the near future. The activities embrace a review of the suitability of previous risk treatments, including an adjustment if necessary and estimating the expected likelihood and impact of the risks. Finally, proposals for their treatment are developed. At the end of the pre-meeting step, the purchasing plan is

finalised and forwarded to the pre-meeting, together with the risk assessment results and the proposals and adjustments for risk treatment.

The cross-functional pre-meeting step is used for a final review and decision-making within a tactical and operational planning horizon. Accordingly, sales, commercial intelligence, and purchasing representatives meet to review the results of the risk monitoring and assessment activities of the demand planning and supply planning steps. Based on the reviews, adjustments can be made. Then, the proposed risk treatments are reviewed, and a decision is made on one treatment. Sometimes, in this specific sector and industry, suppliers may change their supply promises towards the end of the month, which can lead to the exposure of short-term risks that require immediate reaction. These short-term risks, thus, affect Firm C's operational SCP but are often discussed within the scope of S&OP. As mentioned before, this should be handled differently in the future through an additional planning process. The pre-meeting step ends with an agreed S&OP plan and a decision on risk treatment. In case any risks with strategic impacts were identified within the demand planning and supply planning steps, the executive meeting step involves executives from sales, operations, and finance. It is used to assess and treat those risks. Moreover, the executive meeting step is useful for providing a brief report about decisions on risks with tactical impacts. By this, the step is applied to ensure alignment with strategic SCP.

## 4.2 Cross-case analysis

The within-case analysis reveals in-depth insights into how the three studied firms have adapted their S&OP processes to dynamic and complex supply chains. The cross-case analysis reveals that the firms share several commonalities. Thus, it enables the development of propositions for such an adaptation, thereby directly addressing this paper's research question. Table 4 provides an overview of the adaptations as interventions to address one or more specific characteristics of dynamic and complex supply chains, i.e., CAS constructs. The concrete adaptations and the resulting propositions are further introduced next.

The findings reveal that Firms A and B have adapted their S&OP by parsing the process. This means the firms run one dedicated S&OP process for each business

**Table 4** S&OP process adaptations to address CAS constructs

| Adaptation  | Main construct(s) addressed   | Realized by firms | Related to proposition |
|---|---|-------------------|------------------------|
| Parsing the S&OP process  | Agents; dimensionality; rugged landscape  | A, B              | 1                      |
| Integrating SCRM activities   | Self-organization and emergence; connectivity; dimensionality; dynamism                   | A, B, C           | 2                      |
| Involving finance and executives                                      | Agents; dynamism; dimensionality, rugged landscape  | B, C              | 3                      |
| Implementing additional process for linking S&OP with operational SCP | Dimensionality; dynamism  | A, B, C           | 4                      |
| Utilising sophisticated information technology                        | Self-organization and emergence; connectivity; dimensionality; dynamism; rugged landscape | A, B, C           | 5                      |

unit. The reasons behind this decision is based on the different contexts of the corresponding business units. First, each firm's business unit is part of its own dynamic and complex supply chain, embracing a multitude of suppliers and customers located and distributed worldwide ("Agents" construct). Parsing the process enables the firm to deal with supplier- and customer-specific actions that may differ from those in other business units. Second, each business unit is confronted with different legislations and regulatory requirements, making it impossible to follow a "one-rule-fits-all" approach for all products in their portfolios. Instead, a dedicated focus on those products associated with one business unit and their specific requirements is considered highly valuable. While Firms A and B have parsed their S&OP processes to address different agents dealing with external factors that limit the degree of their decision-making process ("Dimensionality" and "Rugged landscape" constructs), Firm C still runs one single S&OP process. Although Firm C operates in a dynamic and complex supply chain, it considers one S&OP process sufficient. However, in a workshop, the executive emphasised that parsing may be necessary if the firm continues to grow and increases its product distribution portfolio. Consequently, the first proposition (P1) is as follows:

**P1:** *To deal with dynamic and complex supply chains, firms could parse their S&OP process.*

All firms have adapted their S&OP process by integrating SCRM activities. More precisely, a generalisable pattern can be discovered for the demand planning, supply planning, and pre-meeting steps. Accordingly, risk monitoring should be conducted first as it is an "important basis for the other SCRM activities" (executive at Firm C). It enables firms to understand better what is happening within their supply chains and beyond, e.g., supplier and customer actions or new legislations ("Self-organization and emergence" and "Dynamism" constructs). Based on the monitoring, risks should then be assessed and treated. These two SCRM activities facilitate the evaluation of any changes within and beyond their supply chains in terms of how and why these changes have emerged, what is their impact on the firm, and what may be suitable responses ("Connectivity" and "Dimensionality" constructs). Following these three activities is only possible when a firm has already identified risks. However, the activity of identifying risks is not considered necessary to be integrated within the S&OP process but rather outside, e.g., within another business process of the firm. As a consequence, the second proposition (P2) can be formulated:

**P2:** *To deal with dynamic and complex supply chains, firms could integrate risk monitoring, risk assessment, and risk treatment activities into the demand planning, supply planning, and pre-meeting steps of their S&OP processes.*

When facing a high degree of uncertainty, effective decision-making in S&OP is challenged ("Dynamism" and "Dimensionality" constructs). Although uncertainty will still remain, it is, therefore, a suitable approach to base decision-making on more information. Traditionally, S&OP decision-making often relies on the possible effects on volumes (e.g., demand volumes, production volumes, etc.). Firms B and C have

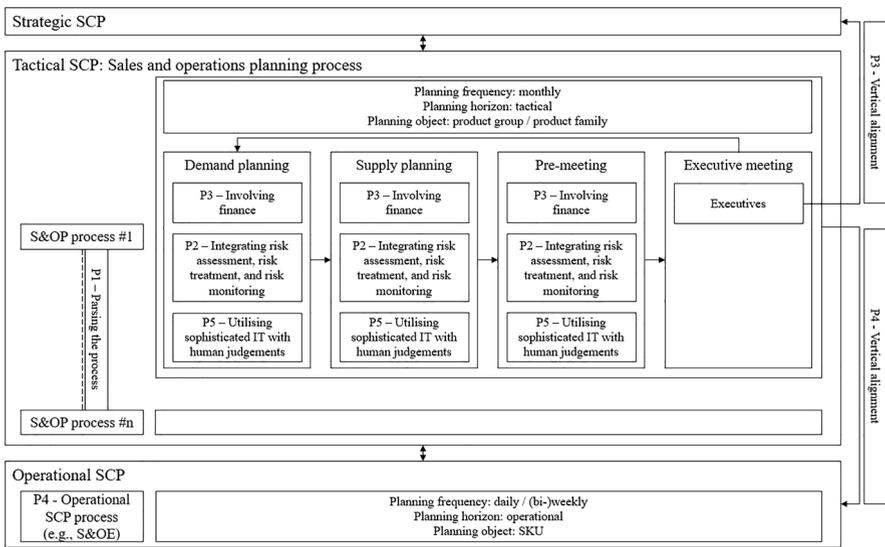
adapted their S&OP process by also involving finance representatives to incorporate a financial perspective when, in particular, assessing and treating risks. It enables a more profound evaluation and decision-making. Additionally, several factors need to be considered that are outside the scope and mind-set of tactical SCP representatives from sales, marketing, or operations (“Agents” and “Rugged landscape” constructs). For instance, when making decisions, it needs to be ensured that they are aligned with the overall business strategy and strategic SCP. Therefore, executives play an essential role at Firms B and C to ensure the effective linkage between tactical SCP through the S&OP process and strategic SCP. The third proposition (P3), therefore, is as follows:

**P3:** *To deal with dynamic and complex supply chains, firms could involve finance representatives in the demand planning, supply planning, and pre-meeting steps of their S&OP processes. Additionally, executives could play an important role in ensuring a strong vertical alignment between tactical and strategic SCP.*

An effective vertical alignment between tactical and strategic SCP is one important linkage that needs to be built in dynamic and complex supply chains. The other refers to the interplay between tactical and operational SCP. Particularly, in highly uncertain supply chains (“Dynamism” construct) where many unexpected external events can occur (“Dimensionality” construct), it is essential to build such a strong linkage. Firms A and B, therefore, have an additional process for operational SCP in place. Firm A runs it mainly to deal with unexpected events on the supply side, whereas Firm B runs an even more holistic S&OE process for managing any event that requires immediate response. Both firms ensure an effective information exchange between their S&OP and operational SCP processes. Firm C currently handles unexpected short-term events within their S&OP process but has already recognised that S&OP is not an adequate platform for this purpose. Instead, an additional process is needed with a higher planning frequency, a lower planning horizon, and a more detailed planning object than S&OP, similar to Firms A and B. Therefore, the following fourth proposition (P4) can be formulated:

**P4:** *To deal with dynamic and complex supply chains, firms could implement an additional process for operational SCP. This process is linked closely with the S&OP process to ensure a strong vertical alignment between tactical and operational SCP. It is characterised by a higher planning frequency, a lower planning horizon, and a more detailed planning object than the S&OP process.*

All firms have emphasised that S&OP is a “people process” (exemplary statement from the executive at Firm C). However, they have acknowledged that technological aid is pivotal in dealing with dynamics and complexities in their supply chains. Firms A and B run scenario analyses, mainly for assessing risks, making it possible to evaluate better the impacts of changes in their supply chains and beyond (“Self-organization and emergence”, “Connectivity”, “Dimensionality”, and “Dynamism” constructs), as well as the possible success of their decisions (“Rugged landscape” construct). Firm C currently lacks such functionality but plans to implement AI-based



**Fig. 2** A framework for adapting the S&OP process to dynamic and complex supply chains

algorithms in the future for these purposes. However, the firms emphasise that decisions should never be based on technological aid alone. Instead, a combination with human judgements is highly necessary as AI and other technologies are limited in understanding novel impacts of changes that have never appeared like this in the past. As a consequence, the fifth proposition (P5) is as follows:

**P5:** *To deal with dynamic and complex supply chains, firms could combine modern information technology capabilities with human judgements.*

The five propositions offered within this subsection can be synthesised and consolidated along the traditional S&OP process from Fig. 1, culminating in the framework illustrated in Fig. 2.

## 5 Discussion

This paper sheds new light on the SCP literature by studying S&OP, a traditional SCP process on a tactical level, within dynamic and complex supply chains. Research findings confirm that the traditional assumption of a stable business environment with reliable demand and supply predictable is no longer appropriate to face today's firms' realities (Christopher and Holweg 2017; Sodhi and Tang 2021; Browning et al. 2023). Instead, firms are challenged to adapt their traditional S&OP process to face a high level of dynamism and complexity within their supply chains. More precisely, they need to be aligned to concrete characteristics of these dynamic and complex supply chains, i.e., to the constructs of a CAS. The research findings reveal how S&OP processes could be adapted to address these constructs. They result in five

propositions that advance the theoretical understanding of S&OP in such a challenging setting.

Accordingly, S&OP processes could be parsed to reduce complexity among the potentially high number of suppliers and customers and all the external factors that affect each of them. In fact, two of the three firms studied run more than one S&OP process to address supply chains as multi-agent systems with external factors that limit the degree of their decision-makings in a rugged landscape. This finding corroborates previous studies. For instance, Lapide (2011) suggests parsing the S&OP process when there are multiple sources, with each source dedicated to one specific sales region, or when there are dedicated regional sources. Other authors, e.g., Dittfeld et al. (2021) or Seeling et al. (2021), differentiate between several local S&OP processes focusing on one specific region each and one global S&OP process aggregating the local ones. As another example, Bagni et al. (2022) propose having one S&OP process for established products and one for recently introduced ones. Kristensen and Jonsson (2018) have discovered additional studies where firms run more than one S&OP process.

Integrating SCRM activities into the S&OP process is an adaptation that all three firms follow. This type of adaptation has been recognised as a “best-in-class” characteristic (Noroozi and Wikner 2017, p. 141) of many firms, but research has lacked more insights for a long time (Kreuter et al. 2022). Only recently, Dittfeld et al. (2021) and Kalla et al. (2025) have investigated this topic further. The findings of this paper extend their conclusions. Accordingly, this paper confirms the high value of integrating risk assessment and treatment activities into the S&OP processes. At the same time, this paper's findings show the need to monitor risks first, which is a novel finding to S&OP research. Following this approach would enable an improved understanding of the self-organised and emergent, connected, and dimensioned nature of supply chains. Additionally, it facilitates a proactive management of risks and external factors that could be exposed at any time in a highly dynamic setting. However, while Dittfeld et al. (2021) emphasise the need for identifying risks within S&OP and Kalla et al. (2025) associate it with being a context-dependent activity, this study shows that risk identification should not take place within the S&OP process. Instead, it should be conducted within the scope of another firm's business process.

An adaptation of the S&OP process should also take place on the people level. Accordingly, the findings reveal that finance representatives should be involved in the demand planning, supply planning, and pre-meeting steps of the S&OP process, thereby confirming a recent study from Seeling et al. (2022). Their expertise and knowledge complement the traditional volume perspective in S&OP with a financial one. This is considered highly important as decisions on coping with dynamic and complex supply chains are often associated with higher investments challenging a firm's budget. In this regard, it is equally important to notice and understand the role of executives within the S&OP process. Although executives have been considered a traditional S&OP actor (e.g., Wallace and Stahl 2008; Kreuter et al. 2021), their role becomes even more essential in an adapted S&OP process to dynamic and complex supply chains. Herein, they need to ensure that decisions are in line with the firm's overall business strategy and its strategic SCP, corroborating Goh and Eldridge

(2019), Desmet (2021) and Neto et al. (2024). By this, they aim to ensure and establish an effective vertical alignment between tactical and strategic SCP.

In line with this, firms should not extend the scope of their S&OP processes even when challenged by dynamic and complex supply chains. More precisely, S&OP should remain a tactical SCP process, in line with Neto et al. (2024). However, all firms studied tended to manage issues within their S&OP that are outside the scope of a tactical SCP process. Instead, if there are any short-term issues to be managed, they should be forwarded to an additional operational SCP process, such as quick response (as, for instance, also suggested by Bower 2018; Lapide 2022) or S&OE (e.g., Hainey 2022; Dombroski 2024). This operational process enables a more effective management of all issues that can arise in a highly dynamic supply chain with a high level of dimensionality among the firm's suppliers and customers. The operational process differs from S&OP by realised with a higher planning frequency, a lower planning horizon, and a more detailed planning object, confirming Kalla et al. (2025). A strong linkage between S&OP and such an operational SCP process is necessary to ensure a vertical alignment. However, they should be managed separately.

The findings also show that relying on historical data and applying classical statistical methods in spreadsheets, ERP, or APS systems alone is no longer sufficient to deal with a supply chain and its dynamic and complex nature. Instead, more analytical IT systems are required to gather and process real-time data from inside and outside the firm or define, run, and analyse different scenarios. These functionalities can support coping with those supply chains, particularly in risk monitoring and risk assessment, as shown in this research. Therefore, this paper confirms recent studies on the importance of sophisticated technological aid for SCP in dynamic and complex supply chains (Xu et al. 2021; Kalla et al. 2023; Xu and Pero 2023; Sengupta et al. 2024). However, firms should not rely on and trust novel and innovative IT systems alone. All three firms studied also incorporate human judgements. Consequently, they follow a combination of quantitative and qualitative approaches to deal with dynamic and complex supply chains. This finding corroborates Browning et al. (2023), who encourage such a combination as humans are better able to understand contextual connections and can consider "last-minute 'inside' or 'soft' information, such as short notice of a competitor's advertising campaign, a snowstorm delaying a shipment, or a heat wave increasing ice cream sales" (p. 1844).

Although this study is viewed through the lens of CAS theory, this paper brings additional insights to confirm the context-specific nature of S&OP, proven by, for instance, Kristensen and Jonsson (2018) and Kreuter et al. (2021). Accordingly, the sector and industry can strongly influence how a firm adapts its S&OP process. Firm A, for instance, does not yet embrace manufacturing-related and supply-related risks as it operates in a setting where S&OP is oriented towards fulfilling demand only. Besides, the operations strategy can affect the adaptation. Firm C is a distributor with a purchase-to-stock strategy. This strategy requires balancing the expected customer demand and how many goods to purchase (Ni 2019). It indicates the need to conduct the supply planning step in a cross-functional setting, embracing both demand-sided and supply-sided functional areas. At Firm C, this is reflected by the involvement of sales in this step. In this regard, this paper is one of the first to investigate S&OP beyond the borders of a manufacturing firm. Doing so provides an interesting con-

tribution as studies on S&OP applications at other supply chain members (besides manufacturers) are still rare (Dreyer et al. 2018; Kreuter et al. 2022). The results reinforce that on a high level, the S&OP process of a distributor with a purchase-to-stock strategy can be designed quite similarly to a manufacturer. However, important differences were observed on a more detailed level, corroborating Kristensen and Jonsson (2018) and Kreuter et al. (2021).

The case study's findings also reveal that the five traditional steps of the S&OP process (data gathering, demand planning, supply planning, pre-meeting, executive meeting), as defined by Wallace and Stahl (2008), seem outdated nowadays. None of the three investigated firms has a dedicated data gathering step. Accordingly, due to recent technological developments in automation, this step no longer needs to be considered an explicit first step. Instead, it is rather "naturally" part of certain or all the other four steps. This finding aligns with several recent empirical studies that show the absence of the explicit data gathering step in industry (Dittfeld et al. 2021; Kreuter et al. 2021; Seeling et al. 2021; Kalla et al. 2025).

## 6 Conclusion

This paper introduces a novel framework for adapting the traditional S&OP process to dynamic and complex supply chains, derived from empirical findings from a multiple case study involving three firms. The framework encompasses propositions designed to address the paper's research question on how can the S&OP process be adapted to dynamic and complex supply chains, suggesting that firms can: (P1) parse their S&OP process; (P2) integrate the SCRM activities for risk assessment, treatment, and monitoring activities into the process; (P3) involve finance representatives and senior executives; (P4) establish a closer linkage with operational planning through an additional process; and (P5) utilise sophisticated IT solutions with human judgement to enhance effectively in such a setting.

The research provides both theoretical and practical contributions. From a theoretical perspective, this paper presents the pioneering application of CAS theory within the S&OP domain. This innovative theoretical approach has proven effective in capturing the characteristics of systems "under continuous change." Such insights have led to the development of the proposed novel framework, contributing to the advancement of a unified S&OP theory that aligns with the dynamic and complex nature of modern supply chains. From a practical standpoint, the research findings offer valuable guidance for managers striving to adapt their S&OP processes to the realities of highly dynamic and complex supply chains in which their organisations operate. Moving beyond the traditional assumption of static supply chains, this research enhances the understanding of S&OP phenomena and provides actionable insights for improving operational decision-making in such settings. Therefore, the paper bridges a critical gap between theoretical advancements and practical needs within the S&OP domain, extending the boundaries of knowledge and setting the stage for future studies and applications.

However, the findings of this paper should be interpreted in light of certain limitations, which open avenues for future investigations. First, while three firms operating

in different contexts were investigated, further empirical studies are required to test the propositions and advance the theory development cycle for S&OP. Surveys or additional case studies involving a larger number of firms are considered promising directions. It may also be beneficial to investigate firms in sectors and industries other than the ones studied, firms with small or small-to-mid firm sizes, or firms with other operation strategies. Second, although the proposed framework serves as guidance for S&OP managers, it does not constitute a concrete artefact they could implement directly as a blueprint. Future research could adopt a design science or action research approach to develop such an artefact. Third, this study employs CAS theory as the primary theoretical lens. As a next step, CAS constructs related to co-evolution could be investigated in combination with the internal mechanisms- and environment-related ones. Additionally, alternative theories, such as information processing theory or panarchy theory, could further advance the theoretical understanding of S&OP in dynamic and complex supply chain settings. Moreover, this paper highlights the need for a close linkage between S&OP and operational SCP processes, such as S&OE. While S&OE appears to be emerging as an important process within SCP, both theoretical and practical knowledge on this topic remains limited and rare. Future research should aim to explore S&OE through both theoretical and empirical approaches to shed more light on this process and facilitate its implementation and integration with the S&OP process.

Finally, the paper's findings reveal the high potential value of utilising sophisticated IT within the S&OP process to deal with dynamic and complex supply chains. However, the research did not explore and further analyse different technologies and their current and future role within S&OP. Considering the current trend among supply chain and operations management scholars toward integrating Industry 4.0 technologies into the S&OP process, future research could delve into an "S&OP 4.0". Such investigations could highlight how the utilisation of Industry 4.0 technologies—such as blockchain, (generative) artificial intelligence, and the Internet of Things—can enhance the reliability and robustness of S&OP. These technologies have the potential to enable faster and more precise decision-making, thereby equipping organisations to navigate the challenges of dynamic and complex supply chains more effectively.

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**Data availability** The data that support the findings of this study are available from the corresponding author upon request.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

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