Master's thesis

2022

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Master's thesis

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Envisioning Digital Twin (DT) Driven Sales and Operational Planning (S&OP) Process

A case study of DT possibilities in S&OP process

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Preface

This is a master thesis written at the department of Industrial Economic and Technology Management at NTNU (Norwegian University of Science and Technology) during the Spring 2022. This thesis is written to finish our study in Project Management Programme with specialisation in Industrial Engineering

This thesis is viewed as an early contribution into the body of knowledge for DT iin S&OP context. This thesis aims to envision how DT can be implemented in S&OP context. Those vision can be used as a point of departure for future research revolving DT application in the S&OP.

We give our deepest gratitude to our supervisor, Heidi Carin Deyer, and our Co-Supervisor, Sourav Sengupta, for their constructive feedback, input, and insight in our thesis. We also want to thank our interviewees for their helpful insight in both DT ad S&OP knowledge, and also about how S&OP is implemented in a company. We hope that this paper can be used as one of the foundations for future research regarding DT application or implementation in S&OP.

Abstract

This thesis investigates the potential impact of Digital Twin (DT) in Sales and Operation Planning (S&OP) context. The goal of the study is to investigate DT in the context of S&OP to identify potential improvement of conventional S&OP. To best of our knowledge, within the scholarly S&OP literature, this is the first attempt to envision DT-driven S&OP process. The purpose of this paper is to determine whether the DT can supplement or improve the conventional S&OP process. The following are the three research questions investigated in the thesis:

- Research question 1: What does a digital twin mean in the context of S&OP?
- Research question 2: Which digital twin capabilities that can be leveraged in S&OP?
- Research question 3: Why and how should digital twin capabilities be leveraged in the S&OP context?

Due to the novelty of this context, the thesis bases its understanding on a literature review of digital twins and operational supply chain management (OSCM), since S&OP is one of the sections within OSCM. To completely comprehend S&OP and their challenges, a case company was examined. The case company investigated was a pharmaceutical company, primarily focusing on their S&OP function. Furthermore, DT expert and S&OP expert interviews were undertaken to comprehend the possibilities of DT implementation and improvement possibilities in S&OP.

Synthesise between DT in OSCM and the properties of S&OP leads to DT definition in S&OP context, which is a digital representation of any entity or system, bringing two-way connection between the physical entity and the digital entity. In the context of sales and operations planning, the digital twin may represent a network of smaller components for example procurement planning or demand planning in the S&OP, or the entire system as one. In this context, the DT's purpose is to enhance the decision-making by analysing the system it operates in. This is achieved through the DT capabilities real-time data gathering and forecasting and simulation-analysis.

It was discovered that in S&OP, decision making is the most apparent problem. This study identified and focused on three demand concerns that could be optimized by the DT capabilities; real-time data gathering and data analysis. In addition to identifying and focusing on two supply concerns, the research identifies in addition to real-time data gathering, scenario analysis along with prediction analysis as countermeasures, which all of them related to decision making that taken by S&OP managers.

This thesis also investigates possible ways for digital twins to be leveraged in S&OP, based on the literature review. The core proposal was to develop a DT of the product, DT of the supply network, and Digital shadow of the customer demand. Lastly, the thesis suggests additional research on the deployment of those DT in specific domains where it needed, as it is necessary to determine an appropriate domain boundary and whether the digital twin can handle the problem presented in this thesis.

Keywords Digital Twin, Sales, Operation, Planning, Manufacturing, Supply Chain, Demand, Supply.

Sammendrag

Denne oppgaven undersøker digital tvilling (DT) i Salgs- og driftsplanlegging (S&OP) kontekst. Målet med studien er å undersøke DT i sammenheng med S&OP for å identifisere potensiell forbedring av konvensjonell S&OP. Så vidt vi vet, innenfor den vitenskapelige S&OP-litteraturen, er dette det første forsøket på å se for seg en DT-drevet S&OP-prosess. Hensikten med denne artikkelen er å finne ut om DT kan supplere eller forbedre den konvensjonelle S&OP-prosessen. Følgende er de tre forskningsspørsmålene som er inkludert i oppgaven:

Forskningsspørsmål 1: Hva betyr en digital tvilling i sammenheng med S&OP??
Forskningsspørsmål 2: Hvilke digitale tvillingegenskaper som kan utnyttes i S&OP
Forskningsspørsmål 3: Hvorfor og hvordan bør digitale tvillingegenskaper utnyttes i S&OP-sammenheng?

Da dette er et svært nytt konsept, baserer oppgaven på en litteraturgjennomgang av digitale tvillinger i operasjonell forsyningskjedeledelse, siden det er sterkt knyttet til salgs- og driftsplanlegging. For å fullstendig forstå S&OP og dets utfordringer, ble et selskap undersøkt. Selskapet er et farmasøytselskap, hvor S&OP prossessen deres ble undersøkt. Videre ble det gjennomført et DT-ekspertintervju og en S&OP-ekspertintervju for å forstå mulighetene for DT-implementering og forbedringsmuligheter i S&OP.

Syntese mellom DT i OSCM og egenskapene til S&OP bidrar til en DT-definisjon i OSCM og egenskapene til S&OP bidrar til en DT-definisjon innen S&OP-kontekst, som er følgende: en digital representasjon av enhver enhet eller system, og bringer toveisforbindelse mellom den fysiske enheten og den digitale enheten. I sammenheng med salgs- og driftsplanlegging kan den digitale tvillingen representere et nettverk av mindre komponenter, for eksempel anskaffelsesplanlegging eller behovsplanlegging i S&OP, eller hele systemet som ett. I denne sammenhengen er DTs formål å forbedre beslutningstakingen ved å analysere systemet den opererer i. Dette oppnås gjennom DT-funksjonene sanntidsdatainnsamling og prognoser og simuleringsanalyse.

Det ble oppdaget at i S&OP er beslutningstaking det mest åpenbare problemet. Denne studien identifiserte og fokuserte på tre etterspørselsproblemer som kunne optimaliseres av DT-funksjonene; sanntids datainnsamling og dataanalyse.. I tillegg til å identifisere og fokusere på to forsyningsproblemer, identifiserer forskningen i tillegg til sanntidsdatainnsamling, scenarioanalyse sammen med prediksjonsanalyse som mottiltak.

Denne oppgaven undersøker også mulige måter å utnytte digitale tvillinger på i S&OP, basert på litteraturgjennomgangen. Kjerneforslaget var å utvikle en DT av leverandørnettverket for å identifisere den ideelle fabrikken for kundedistribusjon. Til slutt foreslår oppgaven ytterligere forskning på distribusjon av DT i disse spesifikke domenene, da det er nødvendig å bestemme en passende domenegrense og om den digitale tvillingen kan håndtere problemet presentert i denne oppgaven.

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List of Abbreviations (or Symbols)

DT	Digital Twin
DM	Digital Model
DS	Digital Shadow
SC	Supply Chain
OSCM	Operation and Supply Chain Management
S&OP	Sales and Operational Planning

1 Introduction

In the past decade globalization, market uncertainty and increasing supply chain complexity has elevated the need for integrated and cross-function planning in any organization (Pereira et al., 2020). In the interest of maximizing an organization's global value, seamless planning optimized concurrently in regards to demand and supply will grant overall profitability (Pereira et al., 2020). Sales and operations planning (S&OP) is a tactical planning process. This process is applied to balance demand and supply, and ultimately ensure that various business functions in the organization aligns with the strategic business plans (Ivert & Jonsson, 2014). S&OP is fully integrated supply-chain planning, while also meeting general business objectives (Ivert & Jonsson, 2014; Pereira et al., 2020).

Supply chains are vulnerable to external factors, as in the past decade the global supply chains have been affected by the covid-19 pandemic, the war in Ukraine, and the Suez Canal blockage in 2021. Amongst the many areas Covid-19 has impacted, the global supply chains have also been profoundly impacted. Global supply chains across several industries have had reduced access to markets and materials, resulting in significant operational and financial impacts on organizations (Burgos & Ivanov, 2021). During the pandemic, many industries experienced drastic falls or spikes in demand (Burgos & Ivanov, 2021). Consequently, many organizations have had to quickly respond and react to crises. For instance, processing industries were affected by social distancing rules and other corona-related measures, to decrease the spread of the virus. This led to reduced operations efficiency. Corona infected workers and other bottlenecks have also disrupted the movement of products in regard to transportation (Burgos & Ivanov, 2021).

Putin's invasion of Ukraine has had a rippling effect on the global inter-connected supply chains (Ram Ganeshan, 2022). The war is affecting raw materials from Ukraine and Russia, distribution, and geopolitics, and there is also supply chain politics involved. In order to cut costs, retain market position or gain competitive advantage, many companies in the 1990s began outsourcing, offshoring, and lean manufacturing. As supply chains became part of the global hub, the dependency between countries increased. For instance, many western countries outsourced to China, making the country a major manufacturing hub to serve global markets (David Simchi-Levi, 2022). China being one of the largest countries with production capacity, is reluctant to sanction Russia, and as there is already an ongoing trade war between China and US, therefore many western companies are planning on moving away from outsourcing (Ram Ganeshan, 2022).

Another unexpected event that affected the global SC was the Suez Canal blockage in 2021. A big cargo ship was blocked in one of the busiest shipping waterways for nearly a week. The blockage created a chain of disruptions in the global supply chain, taking a toll on already crowded ports, railyards, and distribution facilities. Which contributed to containership shortages, which then caused delays in shipments, including raw material deliveries, which then had an impact on downstream production and consumer goods manufacturing (Jaeger, 2022).

As a result of all these uncertainties and volatilities, global supply chains are being forced to adapt at a rapid pace. As well as adjusting to consumer constraints involving smaller quantities, greater variety, richer customisation, higher quality, shorter delivery and product life cycle have become increasingly prevalent. Often, functional departments in organizations lack vertical and horizontal alignment. The results are information flow delays and amplification, inadequate corporate strategies, uncoordinated company responses, insufficient operational flexibility, and supply and demand disparities (Wagner et al., 2019). In this context, firms must be able to adapt quickly while maintaining overall efficiency and cost (Affonso et al., 2008). According to Pereira et al. (2020). cross-functional planning can boost the performance of an organization and maximize its global value. S&OP is therefore an essential planning process to combat these problems. As S&OP can through tactical planning balance the demand and supply, and guarantee that the plans for the various business operations support the strategic business plan (Ivert & Jonsson, 2014). The seamless planning concurrently optimized for demand and supply will improve not only sales revenues or operational efficiency, but also overall profitability. Sales and operations planning will also provide more aligned operational and strategic plans, and a better balance of supply and demand would benefit enterprises in the form of less inventory, more utilisation, cheaper costs, and more satisfied customers, as well as increase their competitive advantage (Wagner et al., 2019).

S&OP can be divided into two; the planning side and then the people side. The planning side consist of set of planning rules, procedures, alignment meetings, and performance measurements. While the people side consists of more soft aspects like collaboration, culture and executive support. However, establishing all of these measures is tough, which may explain why some organizations are unable to reap the projected benefits from S&OP implementation. There are different maturity states for the S&OP implementation. One level is for instance, undeveloped, where there is a total lack of collaboration and planning tools in a company. The opposite would be an advanced maturity state with structured processes throughout the supply chain, with seamless demand and supply planning optimised concurrently to maximize the overall profitability (Pereira, 2020). Nevertheless, having an advanced S&OP is difficult, as both the planning side and the people side have to be seamlessly collaborating. Another challenge in S&OP is due to the fragility of tangible documents. As there are many hundreds of physical documents that has to be dealt with in the S&OP, there is a great possibility that there are some documents that becomes disintegrated or even lost. For instance, historical sales data can be lost from the hundreds of binders that some production facilities use today. Human error and the challenges of reviewing years of previous data to estimate demand have led to inaccuracies when using Excel sheets. As much as forty percent of manufacturers struggle to fulfil customer orders due to these defects (Howard, 2020).

Many scholars have also argued that the traditional S&OP method must be centred on advanced planning and scheduling systems. Supporting S&OP processes requires functionalities such as integral planning, constraint-based planning, optimization, and what-if simulation, especially if the planning complexity is high (Pereira et al., 2020). Therefore, an advanced technology like a digital twin is needed to support these constraints.

Digital twins (DT) are virtual real-time representations of physical objects. The digital twin technology consists of a physical product and a digital replication of the physical product. There is a two-way connection between the physical and digital products, such that if the state of the physical product changes, so does the state of the digital product, and vice versa (Saputro & Sridaran, 2021). The DT has been researched in various context such as meteorology, health, meteorology, manufacturing and process technology, education and in cities, transportation and energy sector (Rasheed et al. 2020). In recent years DT has piqued the interest of the operations and supply chain management (OSCM) scholars. Accordingly, there is a growing trend in DT research spanning manufacturing, logistics, and supply chains (Dolgui et al., 2020; Li, Fu, et al., 2021; Marmolejo-Saucedo, 2020; Park, Son, et al., 2021). The digital twin has been applied in these industries for different purposes like optimization, simulation, prediction and data sharing in real-time (Ding et al. 2019).

To achieve an advanced S&OP process, the maturity must be improved. In the most advanced stages, all IT systems within an organization are totally automated. Integrated solutions would optimize both sales decisions, like pricing, and operations decisions, like production schedules. The S&OP process of the future should rely on advanced planning and scheduling technology. As stated previously, optimisation and what-if simulation are crucial to S&OP procedures (Pereira, 2020). Therefore, the need for a digital twin in sales and operations planning is highly needed, to improve and optimize the maturity and efficiency of the S&OP process. Exhaustive search on DT literature within S&OP context present zero result, hence it can be concluded that Digital Twins in S&OP has to date (2022) not been researched. Consequently, this thesis intends to explore the possibilities of digital twin in sales and operations planning.

1.1 Research Question

In light of this, further research must be conducted on DT in S&OP context. This paper intends to analyse how DT has been applied in closely related domains to S&OP, such as OSCM, in order to examine the potential uses of DT in S&OP. On this basis, three primary research questions were developed:

1. What does a digital twin mean in the context of S&OP?
2. Which digital twin capabilities that can be leveraged in S&OP
3. Why and how should digital twin capabilities be leveraged in the S&OP context?

Based on the preceding problem description, the goal of this thesis is to: (1) comprehend the context of DT in S&OP; (2) provide DT capabilities that will aid in enhancing conventional S&OP; and (3) present a viable strategy of implementation or leveraging DT in S&OP.

1.2 Scope of Research

There are two main subject domains in this study, which are DT and S&OP. The scope of this study is illustrated in the Figure 1.

In integrated planning, S&OP processes are important areas. Supply chain planning has several levels, but S&OP concerns are on how to manage supply and demand in the system. This becomes the basis of S&OP context within this thesis. The scope should include component that build S&OP, from its definition, process, and how it connected with other areas such as supply chain function. On another hand, DT are transformative technology that can help transform conventional process or system, such as production, manufacturing or even supply chain system to increase efficiency and reduce costs. By investigating the properties of DT and how it can leverage the system where it has been applied, the knowledge to implement the DT can be achieved. Thus, the scopes of DT are limited to the Development of DT, DT Definition, DT capabilities, and how to implement DT in a system. As there are a vast application of DT, DT application in OSCM will be used as starting point of DT context.

In regard to connecting both, each of these context is extended. To define DT in S&OP and the capabilities it can bring, DT definition and capabilities in OSCM are analysed and by looking at the similarities between OSCM & S&OP context, the definition and capabilities of DT in S&OP can be proposed. As the research in this area is quite niche, there is also a need for input, experience, and study from the expert/practitioner in this area, to know the current and real challenges of DT implementation in S&OP. Therefore, one case interview was conducted to gather a deep understanding of a real-life S&OP function within a company. After extending the S&OP context, the bridge between DT and S&OP is built by using interview from S&OP experts that has experience in DT. This is being done in order to explore the possibilities of DT implementation in the S&OP as it gives view on where the S&OP is lacking and how DT might help. Lastly, the DT view is expanded by interviewing DT expert to explore if these ideas could be implemented and to achieve a richer understanding of DT.

Thus by analysing and gathering knowledge in both DT and S&OP, the question RQ1 can be answered. With the input, and experience from the company, the answer in RQ2 and RQ3 can be answered.

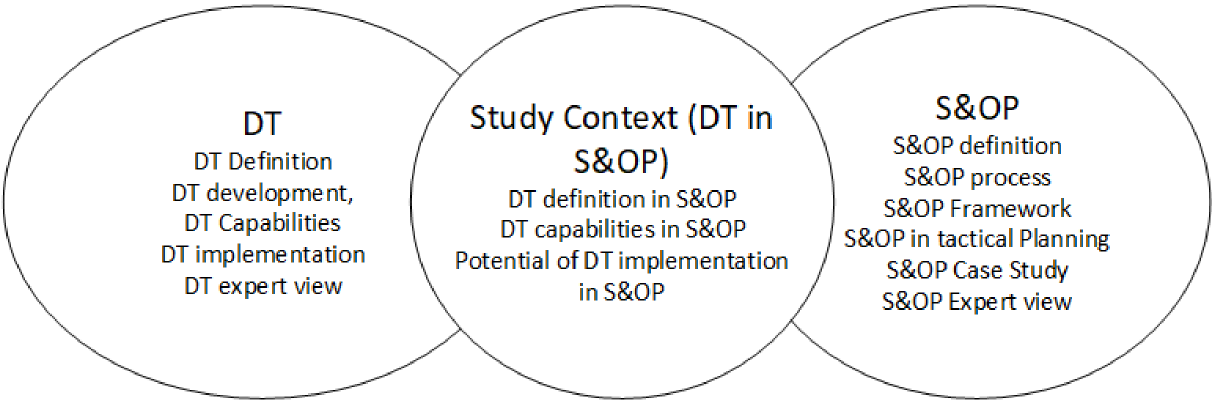

Figure 1 Thesis Context

1.3 Thesis Outline

There are seven chapters in this thesis and Figure 2 shows how each chapter is structured. Each of these chapters contain specific information that will help on understanding how DT can be leveraged in S&OP context.

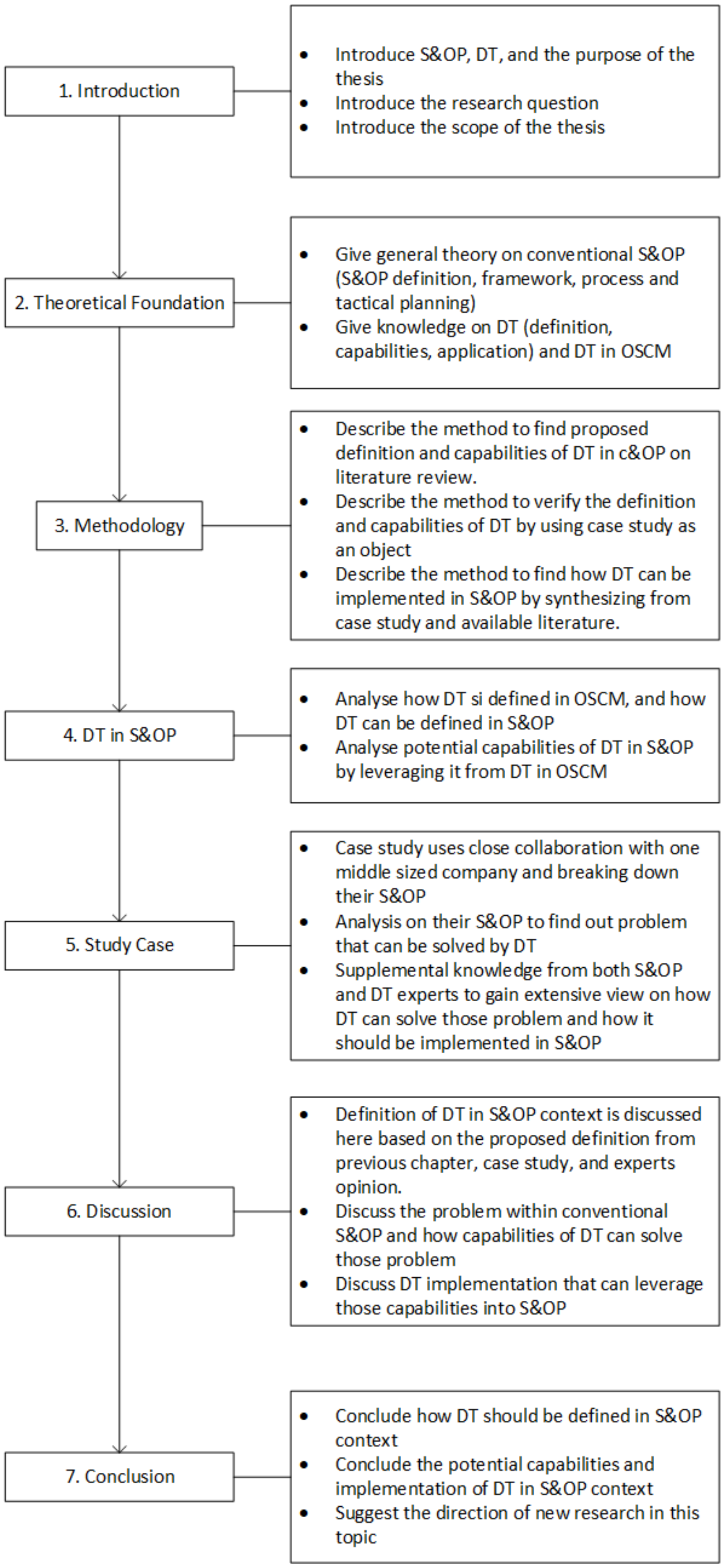

Figure 2 Details of Thesis Structure

2 Theoretical Foundation

The purpose of this chapter is to present the theoretical basis for understanding both sales and operation planning (S&OP) and Digital Twin, as well as the current state of digital twin application within S&OP. This understanding will be used in analysing the empirical part of the research. This theory is built upon literature regarding S&OP and DT, mainly from papers in their respective areas and supplemented by knowledge from website. This section is structured where section 2.1 introduces S&OP, beginning with its definition and progressing to an understanding of S&OP within organizations and how planning is carried out in S&OP. Section 2.2 provides an overview of Digital Twin, from its origins to its various applications. Finally, the application of DT within S&OP is discussed and the understanding S&OP as a context and DT as a transformative technology can be obtained.

2.1 Sales and Operation Planning

This section reviews the body of knowledge on the topics of Sales and Operation Planning (S&OP). Firstly, this chapter will describe the S&OP definition and its objective. Then, properties of S&OP itself in form of S&OP framework and process are being discussed. Lastly, as the topics are related to the planning within S&OP, the tactical plan of S&OP will be explained to understand how it is done.

2.1.1 S&OP Definition and Objective

S&OP is an essential part of Supply Chain Management (SCM), where it seeks, through reconciliation of sales forecasting, company strategy and scheduling of daily operations, to balance demand and necessary supplies (Wolfshorndl et al., 2020)

In Wolfshorndl paper, one key definition of S&OP is to balance supply and demand. There are quite a lot of definition of S&OP that revolves around this concept. Ávila et al. (2019); Grimson and Pyke (2007); Noroozi and Wikner (2017); Schlegel et al. (2020); Thomé et al. (2012) defines S&OP as a process that balances customer demand with supply capabilities. Another similar definition is by Ambrose et al. (2018) who define S&OP as a process that seeks to align customer demand with product supply

Furthermore, Samouche et al. (2020) explains this definition by describing two components of S&OP, Sales planning (based on demand), and production planning (which determines the capacity requirements, inventory levels and the level of order book). However, besides that, Samouche et al. (2020) also includes all the process that link the strategic objectives of the business with the production plan to be part of S&OP.

Similarly, Ávila et al. (2019) has all the same component of S&OP in its definition, where S&OP is described as a cross-functional long term planning process that links different business plans into one integrated set of plans with the main purpose of balancing supply and demand and linking the strategic plans within the firm. The unification of different business plans into an integrated set of plans is also a definition of S&OP by Romão et al. (2021)

Hansali et al. (2021) has a similar definition of S&OP, where it is a process that relates strategic planning to operational activities, also balancing demand and supply chain by performing vertical and horizontal alignment in organisation. Vertically by aligning strategies, objectives, action plans and decision, and horizontally by aligning the objectives of the different organisational functions.

Other definition that widely used is the one that is defined by the American production and inventory control (APICS) as a process to develop tactical plan that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans (Ávila et al., 2019)

Based on all those definitions, there are 3 key point of S&OP in the definition of S&OP, which are:

- Balancing demand and supply
- Create integrated set of plans that links different business plans and strategic plan
- Create horizontal and vertical alignment in organisation

In balancing demand and supply, S&OP managers need to calculate and predict how much demand that the company can take within the capacity of the company (price, time, and quality) including how much they can source the product from the supplier. In the supply side, S&OP managers need to assess the production within the company to make sure all the demand can be met.

In order to make this works, all the function within the supply chain need to be integrated and linked together to create a consensus about the main targets that the company are trying to meet, such as sales volumes, production plan, sourcing plan, etc. This consensus leads to an integrated plan that created by S&OP managers that will be used by all the function such as procurement, production, distribution, and sales function. Outside this horizontal alignment in different function, S&OP also need to include vertical alignment where the integrated plan also includes the strategic plan from the executives. One example of this vertical alignment is when the executives want to have more production in a region such as Asia because it is cheaper, then the integrated plan for production function will be impacted by this decision.

Those three key points shows how S&OP function are defined within a company and what are their objectives. To conclude all the objectives that has been discussed, the objective of S&OP is to create an integrated plan that links different business and strategic plans and create alignment within the organisation to achieve balance in demand and supply. However, there are a lot of elements that can shape and impact those integrated plans. All those elements comes together in a shape of S&OP framework

2.1.2 S&OP Framework

There are a lot of elements that can affect how the integrated plan can come into being, from the environment on the company operates, into both strategical plan from the executives and all the data and plan from each of the supply chain function. Therefore, there is a need to group all those affecting element together. It is necessary to develop a framework that can capture the essential elements of S&OP within each company in order to understand the properties of S&OP and how it differs from one company to another. This is because the process by which each company develops its business plan and performs its organizational alignment is vastly different from that of the other companies.

Those properties include contextual information that defines the characteristics of the environment where the S&OP is developed. This contextual information includes region/country, industry, manufacturing strategy, product-process matrix, level of product aggregation (product family and/or SKUs), hierarchical planning (strategic versus tactical), and planning horizon (short, medium, or long term). Inputs to the S&OP process are regroup functional plans, sales and demand forecasts, inventory, budgets, and operational constraints.

Structure and processes are described through the four basic dimension. Meeting and collaboration regroup participants and promote trust, commitment, and meeting regularity. Organisational aspects include empowerment and the degree of formalisation in the S&OP process (teams, number of steps, and agenda). Information technology is subdivided into systems, software, models, and simulations. Measurements are regrouped under S&OP metrics. All those data help describes how integrated plan comes into being from a horizontal standpoint, where the input data such as demand forecasts, inventory, production plan, and other are being discussed in the meeting with all different function. However, vertical integration with the business and corporate strategic plan is also important. These also needed to be included. Lastly, outcomes becomes the fifth dimension and consist of plan integration between procurement, production, distribution, and sales. The result of the S&OP is profit optimisation.

Thomé et al. (2012) develop S&OP framework that can encompass all of those elements. The purpose of this framework is to figure out all the elements that will affect the integrated plan.

Figure 3 shows framework by Thome et al. (2012). There are 4 central elements in the framework which are context, input, structure and process, and outcomes. Seeing both S&OP process and S&OP framework, it can be discussed that these stages are embedded in both the input and the structure & processes element. In order to further understand the S&OP framework, different elements of the S&OP framework can be described.

Context: It is given that S&OP are influenced by company's operating environment. For

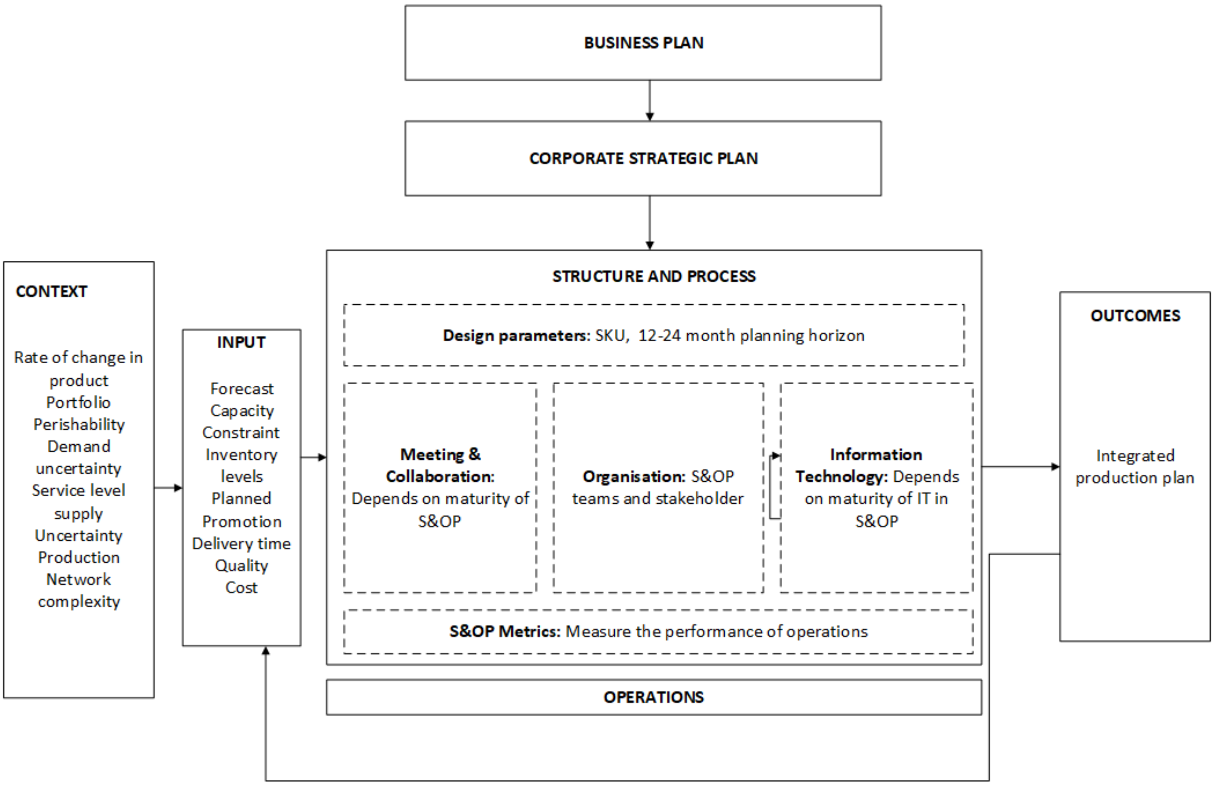

Figure 3 S&OP Framework (Thome et al, 2012)

instances, where the company are located or which industry they are operating will have impact on how S&OP should be designed, Thome listed all the variables that can be added as a context.

Input: Inputs in the S&OP are the data that is needed or considered when creating the S&OP plan. There are several types of inputs where the figure 4 belongs to, which are demand, source, production, delivery, alignment and operational constraints. (Ivert et al., 2014)

Structure and processes: The structure and process element includes (Ivert et al., 2014) :

- *Meetings and collaboration*, where in S&OP, there is a need for regular meetings and for mechanisms to foster trust and build confidence among the team. Meeting regularity varies from monthly to weekly while there are notions that suggest frequent meeting are disruptive and prefer event-driven ad hoc meeting.
- *Organisation*, which related to who should participate in S&OP meetings mainly in the context of the firm: cross-functionality was sought through joint participation in meetings and communication channels by marketing, sales, production, logistics, sourcing, and to a lesser extent, finance.
- *Information technology*, where it is perceived as enabling technologies. The usage of simulation techniques and mathematical models to optimise the integration of the supply and demand side of business as well as the role of advanced planning and scheduling system (APS) in S&OP.

- *S&OP metrics* are the parameters that are used to measure the performance of S&OP. All those parameters written in figure 4 can be divided into a big group which are: Sourcing, Production, and Delivery. S&OP dashboards are instrumental in facilitating regular meetings and keeping up with a set agenda. Dashboards review functional plans and ensure adherence to the plans as measured by the comparison between planned and affected demand, production and inventory, a follow-up of forecast accuracy, and comparison of quantities shipped versus quantities ordered. End results are measured by profit rates and product margins. Although metrics were highlighted in many papers as being very important, none of the papers worked directly with metrics aimed at measuring the S&OP process itself.

Outcome: the proceeding activities and processes lead to an outcome, which usually involves integration of the plans that were input in the process

This framework both serves as the key to understand how integrated plan is conceived from the strategic plans and also as the key elements of S&OP that differs how each companies conceive their integrated S&OP plans. Then, after knowing the key elements that defines S&OP within companies, the S&OP process where an integrated plan is created to balance between supply and demand will be discussed.

2.1.3 S&OP Process

As all the properties has been understood, S&OP process need to be explored as it is a step-by-step process that taken in order to create Integrated plan. In this S&OP Process, all the steps that taken by the S&OP teams to create an integrated plan based on Input that has been explained previously in S&OP framework will be explained.

To balance both demand and supply, an S&OP process is used to create a set of integrated plans within the companies. Usually, S&OP process is done in monthly cycles. There are some steps in the S&OP process. Wolfshorndl et al. (2020) describes 5 steps in S&OP process which are:

- Data Collection
- Demand Planning
- Production Planning
- Preliminary Meeting
- Executive Meeting

Similarly, Ávila et al. (2019) also divided S&OP process into five steps which are:

- create demand forecast
- create initial supply plan,
- develop final consensus operation plan,
- communicate and implement plan, and lastly
- S&OP evaluation.

Another author Seeling et al. (2020) different steps in S&OP process such as:

- Data gathering
- Demand planning
- Supply planning
- Pre-meeting
- Executive meeting

Even though there are a bit differences in the S&OP process that has been proposed, in essence, they all have the same objective, where the first step is to gather data, then use the data for demand planning, then create supply planning, and lastly, there is a need to evaluate and assess the S&OP process by having a meeting between stakeholders. That is why the S&OP process by Wolfshorndl et al. (2020) would be the most suitable to present the S&OP Process.

Figure 4 shows the S&OP processes that developed each week.

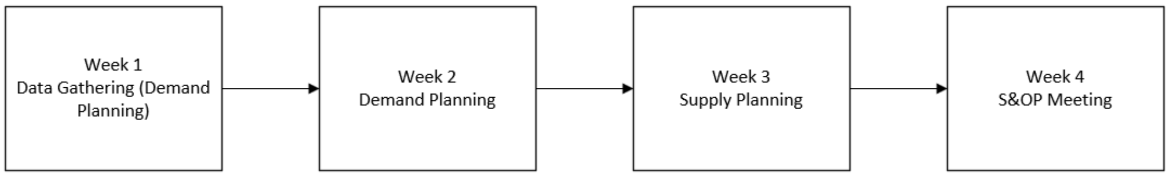

Figure 4 S&OP Process (Wolfshorndl et al. 2020)

In data gathering, the S&OP teams collect the data from customers and the environment to be used for assessing the demand from the customer. In this part, the data that is usually gathered are customer demand and all the data related to that. The second step is demand planning, where all the data are gathered and the forecast for demand are created for the basis to assess how much demand that will be needed that month. The third week is supply planning, where the production plan is created to satisfy the customer demand that has been assessed. Lastly in the fourth week, S&OP meetings are being held to assess the results of the S&OP process within this month. Those meeting can be divided into pre-meeting where it only S&OP team with sales and production team, and executive meeting which include all important stakeholders. However, both meeting has the same goals, which are to assess the results of the S&OP process within this month

This S&OP process is an integral part in understanding S&OP, as in this process both the supply and demand data are gathered from different functions within the supply chain and an integrated plan is created and distributed back to each function to perform the planning. Therefore, the next step in understanding S&OP is to understand how planning is being done in each function especially in supply chain function, as a lot of data for S&OP process and plans that coming from S&OP process are implemented in this function.

2.1.4 S&OP in Tactical Planning

From the previous section, both key elements that affect integrated plan and the process to create the integrated plan within S&OP has been discussed. However, the subject within S&OP, where the data is being gathered and the plan is being implemented is not yet discussed. This section will provide the discussion on four functions within S&OP where the S&OP Plan is being implemented.

Based on S&OP definition, S&OP is a tool to integrate the planning process within the firm. Traditionally, there are four essential functions in the supply chain (procurement, production, distribution, sales) that work independently and linked through the stocks. To create integrated plans within the four supply chain functions, there are four steps based on the supply chain stages. Before the first stage, the board of the company defines the strategic decisions of sales and operations strategic decisions of sales and operations (procurement, production, distribution). Then, the first stage is *procurement planning*. Mid-term procurement planning aims to determine the most efficient acquisition plan of resources from the market in order to satisfy production needs. Second stage is *production planning*. Mid-term production planning has the purpose of determining the most efficient use of the production resources in order to satisfy the demand (Pereira et al., 2020).

Third stage is *distribution planning*, where it bridges the gap between production and the clients. Its primary objective lies in the fulfilment of the estimated demand considering the transportation and warehousing capacity while minimising costs. The fourth or last stage is *sales planning*, where companies aim to create the best sales strategy and the executive boards approve the product portfolio (Pereira et al., 2020).

Figure 5 shows the illustration of the tactical S&OP Process.

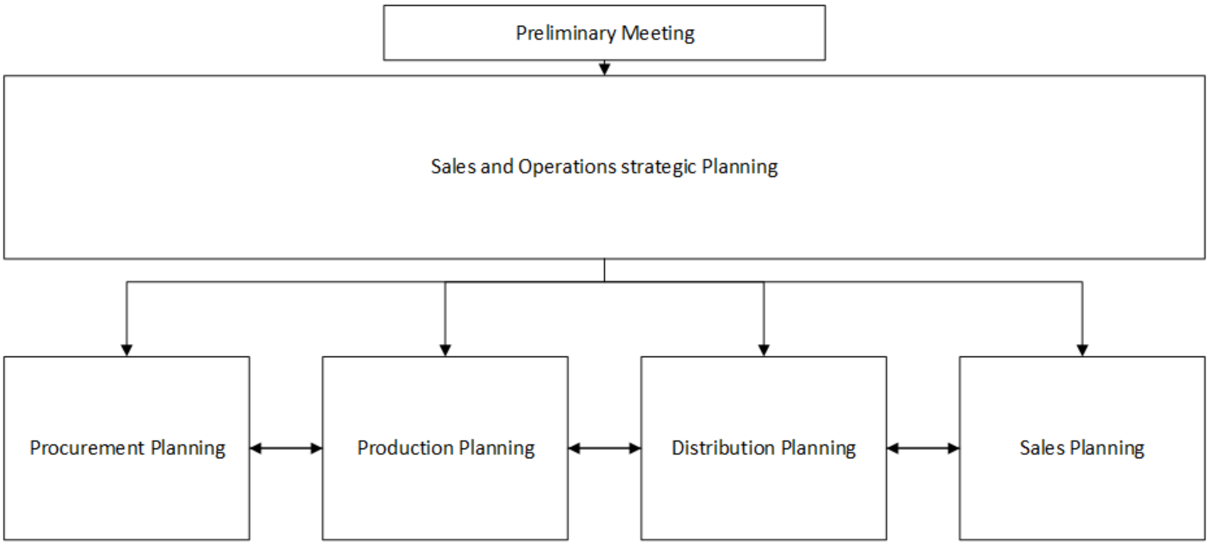

Figure 5 Tactical S&OP Process (Pereira et al., 2020)

It can be seen from Figure 5 that a preliminary meeting creates strategic planning for all the planning processes. One important thing to mention is the connection between each planning step is not one-way but two-ways, where for example the procurement planning will get data about how much product that will be produced from production planning. This happens across the supply chain function from procurement, production, distribution, to sales planning. Each one of them have two-ways connection. To further understand S&OP and how the planning works through all the functions, each of these functions in S&OP tactical planning will be explained.

Production Planning

Production planning is a plan to determine the most efficient production resources to satisfy demand. In order to generate a plan, it is necessary to have demand from customers, available resources from procurement, and other external parameters like production costs, setup costs, and holding costs. The inputs in production planning are production needs, inventories fulfilment, plant locations, or production equipment. From this data, the outcome is a plan of the optimal order quantity that should be placed, which is the production quantities of final products (Dolgui et al.,2020)(Pereira et al. 2020). In some cases, the setup and season-based demand variation are also accounted for.

Decision-making in Production Planning

The main decisions-makings in production planning concerns production quantities, setups, inventory targets and overtime needs. The planning decisions depends on if the environment is a single stage production or a multi-stage production. In multi-stage production environments usually the complexity is reduced, and the decisions concerns using the same resources, similar transportation costs or if the inventory needs to be different and so on. In a single-product context the problems usually relate to pricing of products. (Pereira et al. 2020)

Procurement Planning

The goal in procurement planning is to establish an efficient acquisition plan, using the resources from the market to satisfy production needs. The production needs have to be in order, for the procurement planning to be created, as it is the main input in the procurement planning. The main production needs are raw material needs, hiring needs, and subcontracting needs. While creating the procurement planning external factors like human-labour costs, market availability, supplier capacity, etc. has to be accounted for, as well as department's guidelines like strategic suppliers. The outcome of the procurement planning is a plan that defines the amount of raw materials or final products to order from the market. (Pereira et al. 2020)

Decision-making in Procurement Planning

The main decision-makings in procurement planning involve order quantities, inventory levels, supplying contracts, and workforce requirements. Order quantities and inventory levels face difficulties if they should use one supplier or multiple suppliers, use single material or multiple materials for instance. Inventory targets have to choose if the inventory should be according to demand or if they should have a safety stock if there's a sudden spike in demand for example. Workforce dimensions will also be affected in a sudden spike in demand or seasonal demands, as there has to be employed more workers. Decisions here would be the following: should one have no limitations on hiring and should the company have one type of worker or a multiple-type of workers. Similar pattern decisions will be decided in the procurement planning. (Pereira et al. 2020)

Distribution Planning

The main ambition of the distribution planning is to realize the most cost-efficient transportation and warehousing capacity in regards to the estimated demand. The distribution planning in S&OP has to consider both the production and clients when generating the plan. The input in the distribution planning comes from the sales team, that present the sales for the next periods. Along with external factors such as shipping costs, shipping capacity, warehouse capacity, and the strategic guidelines like distribution location, distribution systems, lead time are also considered. The outcome of the distribution plan is usually a guide for the shipments for the market or client, units of transportation requirements and the final products inventory targets. The plan can also include clients' allocation to specific distribution locations. The shipment quantities in the distribution process can be leveraged down to the production department as production needs. The production department will then report its capabilities of fulfilling future needs in form of inventories. This is then considered in regards to demand, and if they are not satisfied, the distribution team has to negotiate possible measures with the sales team again. (Pereira et al. 2020)

Decision-making in Distribution Planning

In distribution planning the major decisions consist around shipping quantities, units of transportation, inventory targets, demand fulfilment and clients' allocation. When discussing shipping there comes a question on whether to distribute the production directly to the customer or have distribution centres, where you also have to consider other variables like complexity and lead time. The unit of transportation is also a decision-factor that has to be considered, sometimes single transportation mode is preferred and sometimes the multiple transportation mode is used. (Pereira et al. 2020)

Sales Planning

The sales planning specifies the target markets and customer segments for the organization. The inputs for the plan cover the product portfolio which the executive board approves, the demand forecast from reference prices, backlogging costs et cetera, and the operational capacity. However, the outcome is the mid-term sales targets, subsequently from order acceptance and sales backlogging. Sometimes, depending on the company, pricing of the products, promotions and sales contracts to establish with customers are also included in the sales planning in S&OP. (Pereira et al. 2020)

Decision-making in Sales Planning

The most critical decision-making points in sales are order acceptance, sales backlogging, pricing, pricing, promotion and sales contracts. Order acceptance which means that the set demand is not satisfied, and sales backlogging meaning there is a postponement in some orders. The decision is if the sales should handle the order acceptance and backlogging in a customer level or partial aggregation at region level or at global aggregation level. The pricing decisions concerns around if there is a single product or multiple products or if the price stays static for the entire planning horizon, or if it should fluctuate and be dynamic. (Pereira et al. 2020)

2.1.5 S&OP Challenges and Improvement

The conventional S&OP has some challenges. Gallego-García and García-García (2021) outlined several of the obstacles, including big data and analysis, demand factor, and collaboration.

Final goals of demand planning within S&OP is to provide accurate future demand to support decision making (Gallego-García & García-García, 2021). This leads to a need for forecast for the demand planning. However, to create accurate forecast, there is a need to develop models for forecasting demand and evaluating demand projection in different and uncertain condition (Gallego-García & García-García, 2021). To deals with the models in various condition, a big amount of data is needed for the forecasting. With the amount of data handled in S&OP, sorting, managing, and compiling the data has become a difficulty. Additionally, because data collection requires a cost, there is a hurdle in determining what data to collect. Afterwards, analysing those data also becomes difficult without proper technology to synthesise aggregate results from those data.

Other difficulties arise as a result of the effect of factors on demand. Previously in S&OP framework, All the factors within S&OP are being discussed. In those factors, all the factors related to demand are challenging, as it is connected with the customers whether it is external such as covid / pandemic situation, or internal factor such as changes in customer behaviour. Those factors are challenging because of uncertainties within external factors and environment.

Lastly, collaboration is also a challenge for the conventional S&OP. With numerous functions collaborating on a variety of distinct aims and benefits, cooperation that benefits all parties remains a challenge, even more so when there are two conflicting benefits amongst functions. One of the most straightforward conflicts in sales and operations is the sales team’s desire to accept all demand requests to maximize their profit/bonus. On the other hand, the manufacturing team wants to maximize productivity and add only streamlined products to their product line (Dyer, 2019).

2.2 Digital Twin

In the 1970s, when NASA's Apollo program was in its infancy, the digital twin was first introduced. NASA created a replica of spacecraft to determine how the equipment would react during a voyage. In 2012, NASA repurposed the idea and implemented DT in aircraft design and health monitoring. The first broad known application of Digital twin technology was then defined through NASA as *"an integrated multi-physics, multi-scale simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin"* (Glaessgen and Stargel 2012). Later on, large corporations such as GE and Siemens developed DT platforms for real-time monitoring, inspection, and maintenance in 2015. Tao and Zhang (Tao et al., 2019) introduced a five-dimensional digital twin shop-floor system in 2017. The framework investigates the theoretical guidelines for the industrial digitalization of manufacturing. In recent years, from 2017 to the present, DT has experienced unprecedented growth. However, as Digital Twin is expanding its uses in other contexts, so does the definition of Digital Twin. That is why there are a lot of definitions on digital twin depending on the cases that used it. However, to truly understand the concept of digital twins it is necessary to understand the concept of how digital twin was created.

2.2.1 Simulation-based digital model (DM)

Simulation is often defined as the process that creates a model of a system to examine its behaviour under certain conditions. The simulation model is a digital representation of an abstracted version of either an already existing or a future system/object. The simulation can describe, in lower level of detail than in real life, the structure and the behaviour of a system. The information from the simulation model can then be applied to the physical system (Kassen et al., 2021). However, according to Kritzinger et al. (2018) a simulation model or a digital model does not use any form of automated data to exchange between the physical object and the digital object. All data that are used to in a digital model are done in a manual way. Which means that a change in the physical object or system will have no direct effect on the digital object or system (Kritzinger et al., 2018).

One of the huge advantages of advanced simulation models is the possibility to support decision-making. As it can analyse the different system variants, structure and behaviours. Additionally, it can support problem-solving through experiments through the analysis. Consequently, simulation models are useful in operational, tactical, and strategic decision-making in companies (Kassen et al., 2021). In production industry, in order to experiment i.e. build, rebuild, modify an object or material can be costly and time consuming. For this reason, a simulation tool is to greater degree a better solution. The need for constant production adjustments, short delivery times with small batch sizes, simulation can support the production planning and control. The simulation can for instance support through determining the most resource-efficient way in regard to production lot sizes or order sequences. (Kassen et al., 2021)

There are several types of simulations, such as statistical simulations, stochastic simulations, dynamic simulations, system dynamics and multi-agent simulations. Statistical simulations are concerned with spreadsheets, while stochastic simulation is, for instance, Monte Carlo simulations. Dynamic simulations are usually used for looking at processes over time, while system dynamics are used for more socio-economic systems.

Lastly, the multi-agent simulations are used to observe and program the behaviour of “agents” (Kassen et al., 2021). Nevertheless, one special type is the generic simulation, which is an easily applied simulation-tool, if the necessary set of preconditions are set. If a company uses enterprise resource planning (ERP) systems, in order to insert new input data, the generic simulation can be utilized. This is where digital shadows come in. Based on the input data, a simulation model is automatically created as a digital shadow of, for instance, a production. The model can then be enforced by simulated and optimised (Kassen et al., 2021).

2.2.2 Digital Shadows (DS)

According to Renner et al., a digital shadow is defined as an accurate digital model of an existing entity. The digital shadow will be able to predict the behaviour, and describe the whole life span of an entity. The main difference between the digital twin and digital shadows according to Kassen et al. (2021); Renner et al. (2021) are that the digital shadow can be updated with information retrieved from the physical entity, however it cannot return information. The digital shadow cannot go both ways, as it cannot return information to the physical entity (Renner et al., 2021).

According to the literature review from (Kritzinger et al., 2018) digital shadow scholars mostly focus on maintenance, lay-out planning and production planning and control (PPC). The preferred technologies used in these articles were simulation, optimization and use of sensors. Compared to digital twins, there has been more research on digital shadows and digital models. Considering there are far more case-studies and reviews on digital shadows and digital models. Kritzinger et al. (2018) Much like digital shadow there are also, digital siblings which can be considered as copies of the physical entity. The digital sibling does not necessarily have the capability to run in real-time, but is able to do “what-if ?” analysis and risk assessment (Rasheed et al., 2020). However, the digital shadow has the ability to describe a whole life span of a system or entity, as well as predicting the behaviour of the entity. Renner et al. (2021) further explains that the digital shadow is the first step towards a digital twin.

2.2.3 Digital Twin

An explanation of DTs by Kritzinger et al. (2018) is that a DT has data that flows between both the existing physical object and the digital object, and are fully integrated in both directions. This means, as opposed to both the digital model, where there is no data flows, and digital shadows, where there are only one-way data flow, the digital twin can provide two-way data flow. Hereby meaning, that a change in the state of the physical object will also lead to a change in state of the digital object and vice-versa. It is also possible to change and control the digital object, and the physical object will change accordingly.

2.2.4 Digital Twin capabilities

Digital twin is unique as it has the same capabilities as the digital model and digital shadow, but also additional capabilities. Rasheed et al. (2020) explains that the DT can provide real-time monitoring and control, predictive maintenance and scheduling. These capabilities are possible through the implementation of multiple sensors on the physical entity, that will provide real-time information to the digital entity. Digital twin has to ability to provide smart analysis of products in order to detect possible faults in systems in advance. Capabilities of such can have several benefits in planning and scheduling. Since digital twin can provide advanced analytics in real-time, it can contribute to creating an efficient and informed decision support system. The DT can also bring autonomy and gather data information in real-time, which will help teams in departments utilize their time with improving synergies and collaborations, which can also lead to better productivity (Rasheed et al., 2020).

2.2.5 Digital Twin Application

The digital twin technology can be used in a diverse number of industries. The concept can benefit in for instance, health, meteorology, manufacturing and process technology, education, cities, transportation and energy sector (Rasheed et al., 2020).

In the *health* sector the emergence of smart wearable devices, organized storage of health data of individuals and communities, better alignment and personalized medication are rising. The need to intertwine engineering technologies, such as DT, and utilize the capabilities with medical disciplines will be a huge benefit in the health sector.

In *meteorology* DT technology, in form of high fidelity physics simulators and big data technology, are already being applicated to provide long and short term weather prediction.

While *cities, transportation and energy* sector has been using DT to urban planning and changes in power usage. One study delineated a cyber-physical system approach in order to control large scale road freight transportation problems, and minimized fuel consumption by utilizing integrated routing and transport planning.

However, in *education* DT approach that has been outlined by scholars are for instance, a personalized adaptive learning framework that has been constructed using smart learning environment. Among those lines, another study focused on the power of artificial intelligence-powered personalization in online (MOOC) learning.

In *manufacturing and process technology* industries the DT needs are highly necessary, as today's society has a demand for customized, high-quality products in highly variable batches with short delivery times. One application of DT is in smart shop floor, where the machineries can give real-time data to provide how much maximum demand that can be supplied by shop floor. Manufacturing industry is part of the OSCM dimension, which is closely related to S&OP. Therefore, the below section will focus on digital twin in OSCM context and find the correlation between DT in OSCM and DT in S&OP (Rasheed et al., 2020).

2.2.6 Digital Twin in OSCM

The increase of academic research of DT in OSCM, especially spiked during the COVID-19 situation and to achieve competitive advantage. COVID-19 erupted a wave of uncertainty in global supply chains (Saputro and Sridaran, 2021). In China, the supply availability in the global SC was drastically reduced because of the uncertainties in export (Ivanov & Dolgui, 2021). DT has the possibility to provide predictability in short-term and long-term impacts of epidemic outbreaks on the supply chains (Ivanov, 2020). According to Yan et al. (2021) DT can also support strategic management decisions. Consequently, the current research in OSCM and DT has increased.

In the systematic literature review by (Saputro & Sridaran, 2021)it is stated that most of the academic research has been done in manufacturing and supply chain context. The reasoning behind this is that, DT can support several areas and sections throughout the manufacturing and supply chain. The majority of studies of DT in manufacturing context surrounds managing resources. One study used DT for dynamic resource allocation in a factory, while another uses DT to optimize resources for manufacturing in a dynamic environment (Saputro & Sridaran, 2021).While DT in supply chain context, scholars focus on how DT can predict future disruptions and help support the improvement of the continuous cycle of the entire supply chain in real-time (Saputro & Sridaran, 2021).

The review further points out the lack of exploration of DT in production planning and decision making context. Ultimately, emphasizing the need for pursuing unexplored parts of OSCM, which is sales and operation planning, as there are no academical research papers in the study field of S&OP and DT (Saputro & Sridaran, 2021).

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3 Methodology

This chapter's objective is to describe the methodology employed to investigate and answer the report's research questions. In order to obtain a reliable and valid result, the research strategy and design were chosen to answer the research questions that must be thoroughly justified and explained. Second, the literature and protocol for the case study are introduced. The protocols outline the entirety of the procedures necessary for ensuring accurate data collection.

3.1 Research Strategy

According to Bell (2019) many writers find it helpful to find a research strategy for their thesis. A research strategy is a general orientation to the conduct of business research. The two main clusters of strategies are qualitative research and quantitative research. The quantitative strategy emphasizes quantification in the collection and analysis of data and that entails a deductive approach to the relationship between theory and research, in which the emphasis is testing the theories. It also incorporate practices and norms of the natural scientific model and positivism in particular. On the other hand, The qualitative strategy emphasizes in words and images in the collection and analysis of data and predominantly emphasizes an inductive approach to the relationship between theory and research, in which emphasis is placed on the generation of the theories. It rejects the practices of natural scientific model in preference for an emphasis on the way in which individuals interpret their social world. (Bell, 2019).

Both qualitative and quantitative approaches was considered when discussing which research strategy this thesis chose. However, considering the research questions of this thesis, a qualitative research strategy seemed the most appropriate. The thesis focuses on a novel theme, which is digital twin in S&OP. Even though it has started gaining traction between practitioners, exhaustive search on research journal libraries such as Scopus shows that there is still no research paper that focused on the intersection between the two knowledge. Both DT and S&OP should be investigated as a starting point for building knowledge in this new domain. The idea of DT must be brought in from outside of S&OP scope of knowledge, and S&OP itself must be examined in order to identify the regions where these two aspects intersect. Therefore, a qualitative approach which is used for exploratory purposes is best suited to collect deep and rich information. Besides, qualitative research is mostly concerned with words rather than numbers like quantitative research (Bell, 2019). Taking this into consideration, this thesis took a qualitative research design approach to answer what DT means and its capabilities within S&OP context and how it can be implemented.

In qualitative research strategy start from the research question that has been defined. Defining the research question is important as it shows what kind of research strategy that need to be used. To be able to answer the research questions, scope of research based on the research question are defined in the Introduction. In order to achieve an in-depth understanding of the subjects, the researchers of the thesis had to read and analyse papers within the theme and interview experts in the field. After interpreting the data and findings, a conceptual and theoretical understanding was written. Lastly, the thesis' main findings and conclusion is presented.

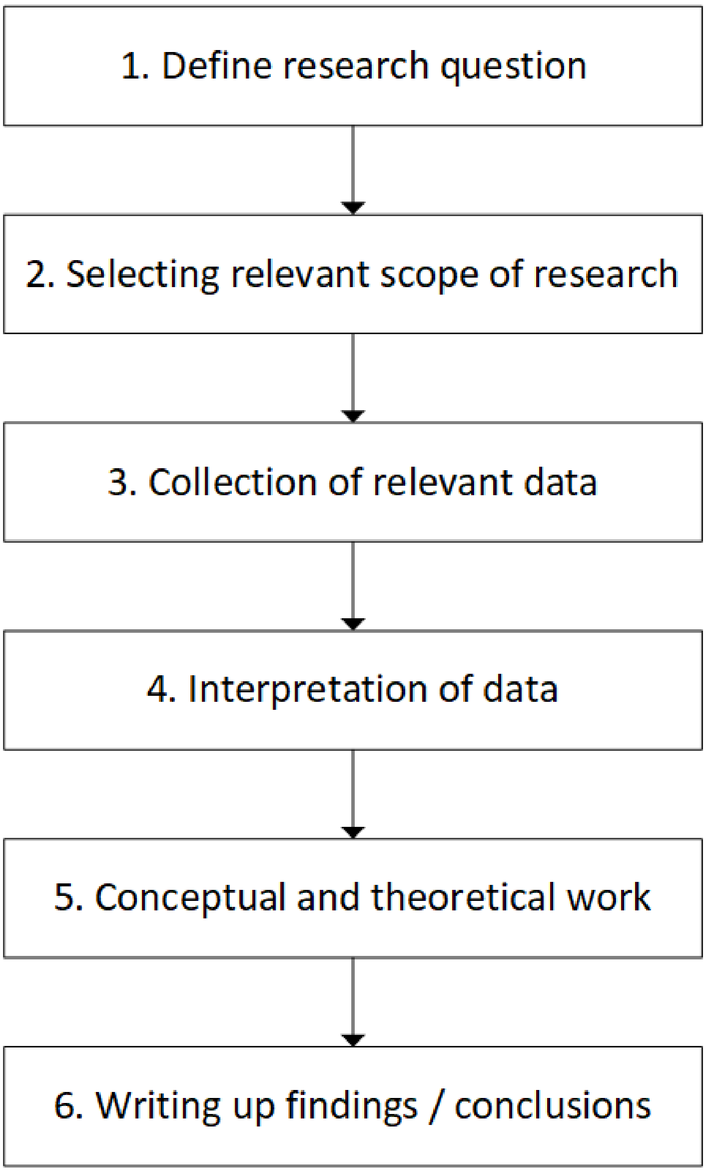

Figure 6 Qualitative research steps

3.2 Research Design

The research design portraits the collection and analysis of data, and the choice of research design reflects decisions about the priority given to a range of dimensions of the research process (Bryman, 2015). When outlining the study, several research designs were considered. To map the project thesis, the research designs by Bell (2019) were taken into consideration. The research designs are explained from a qualitative point of view:

1. *Experimental design:* Usually has no typical form. Is mostly based on experiments. For example, laboratory experiments or field experiments.
2. *Cross-section design:* Entails the collection of data on more than one case at a single point in time. This is to collect a body of data in connection with two or more variables. The data is used to detect patterns of association.
3. *Longitudinal design:* The longitudinal design is a type of research design that is commonly used in business and management research to map change.
4. *Case study:* The fundamental case study comprises a thorough and in-depth examination of a particular case. The complexity and unique nature of the subject in question are the focus of case study research.

5. *Comparative design:* This design comprises the investigation of two or more contrasting situations using almost identical methods. It embodies the logic of comparison, implying that we may better understand social phenomena when they are compared to two or more meaningfully different cases or circumstances.

From an exploratory perspective, the case study design was considered the most appropriate design in order to answer the research questions. Looking at the research question, there are few studies that exist within the dimension of DT and S&OP, which leads to a need of deep understanding of the phenomenon and thus a case study approach is an appropriate one. comparative design study could have been an interesting approach. For instance, comparing how DT is being used in S&OP context in different business sectors. However, a deep understanding is needed and there is no company that already has mature DT application that can be observed, thus case study is a better approach.

In business research, the case study approach is a prominent and is commonly utilized in research design. A case could be a single organization, location, a person or a single event. In this thesis there is conducted two case studies. However, there are different case studies. Explained by Yin (1994), here are three different types of case studies:

- *Explorative case studies:* Initial research of defined problem and form the basis for future researches.
- *Descriptive case studies:* Describe a phenomenon in detail, provide additional information and in-depth understanding.
- *Explanatory case studies:* Conclude and explain the ultimate causes of a phenomena, relationships between variables and effects of factors.

In this thesis, case studies that will be used is the descriptive case studies. As the problem itself regarding the possibility rather than actual problem, descriptive case studies is needed as it can describe phenomenon in detail, and gather all the data that needed for synthesizing the connection between DT and S&OP.

3.3 Literature review protocol

Exhaustive search on the web of knowledge within topics of DT and S&OP produced no relevant results. However, literature exist that described both of this phenomenon separately. This become a challenge in constructing literature to help answering the problem within this topics. When looking at the DT and S&OP, S&OP has a role as a dimension where DT will be implemented. On the other hand, DT is a transformative technology that implemented in different context and dimensions as explained in previous chapter. Therefore, one way to approach the topics of DT in S&OP is to bring DT from bigger dimension of S&OP which is OSCM. To capture the body of knowledge in DT and synthesise it within S&OP context, systematic approach by Denyer & tranfield (2009) are used as inspiration and foundation for the literature review. This is being done by documenting the research strategy used, step by step, so that the reader can access its completeness and the comprehensiveness of the review.

Figure 7 illustrates the five-steps process that needs to be done in a literature review

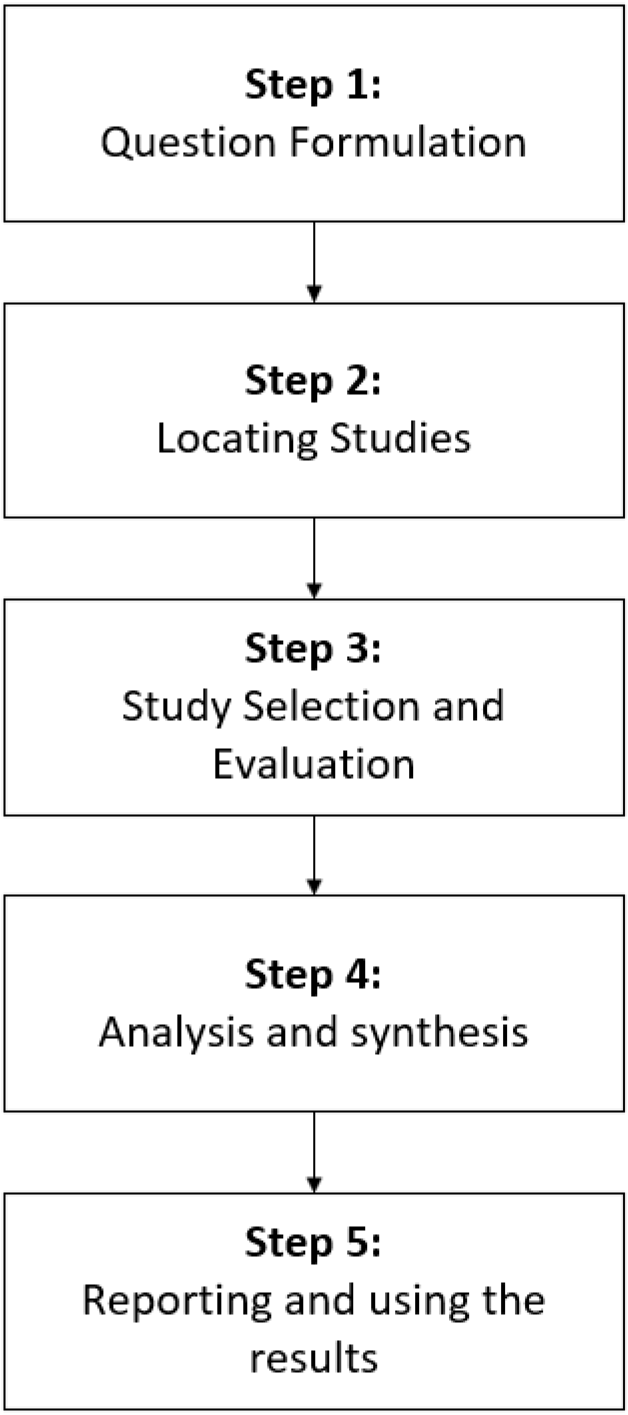

Figure 7 Step-by-step research strategy

3.3.1 Question formulation.

To establish focus and provide guidance for selecting which studies to include and exclude, research question need to be formulated (Denyer & Tranfield, 2009). Research question has been defined based on the background problem that revolves around the possibility of DT implementation within S&OP. There are two question that has been identified from the previous chapter which are: What is the DT definition within S&OP context, and what are the capabilities and implementation of DT within S&OP.

3.3.2 Locating studies

The subsequent step involves determining which databases are appropriate and highly relevant for the research (Denyer & Tranfield, 2009). Scopus was selected because it is a database that cover the majority of research conducted in DT within the context of OSCM. Scopus was also utilized because there are numerous options to filter and export the journal databases, which facilitates the search for relevant papers

To identify the topics or knowledge contained within these databases, a particular search string is required. Users can create a search string by listing relevant terms and connecting them with boolean operators (OR/AND). As the objective is to bring DT into new dimension which are S&OP, the focus are on the definition and capabilities of DT within DT in OSCM, which can be implemented in realm of DT in S&OP

Combining relevant terms with boolean operators (OR/AND) enables the creation of exhaustive search strings for locating and capturing these specific topics. In addition, when an asterisk symbol (*) is employed, the search engine returns any word that begins with the root of the word truncated by the asterisk (e.g., operatio* returns operation, operations, and operational). Using boolean logic, the used search string is shown in Table 1.

Table 1 Search String

Search String	Result
(”Digital Twin” AND ”Supply Chain”) OR (”Digital Twin” AND ”Operatio*”) OR (”Digital Twin” AND ”Productio*”)	1083 Paper

3.3.3 Study selection and evaluation process

In this section, the purpose is to discover relevant papers that can hopefully address the research topic that has been defined. In the selection and assessment phase one will be reviewing the literature sample and pick material based on the relevance in addressing the research objectives (Denyer & Tranfield, 2009). To filter relevant paper, it was important to construct a selection and review process. The selection and evaluation technique that the writers of this study made comprises of searching for the keywords and examine the thousands of literatures represented.

Following exclusion and inclusion criteria were employed while selecting the relevant papers:

- ABS Magazine
  American Business Scholar (ABS) list or Academic Journal Guide is a list released by chartered ABS as the most comprehensive journal guide encompassing 22 subject areas within the field of business and management study. By employing papers published in journals listed by ABS, the quality of the article used in this project study is ensured.
- Title and abstract that are relevant and cantered on DT in OSCM. By examining the title and abstract, works unrelated to DT in OSCM context were eliminated.
- Relevant full-text article cantered on the application of DT within OSCM. As the purpose is to move DT from OSCM into the smaller scope which is S&OP, the OSCM application of DT would provide insight into what DT is, its capabilities, and how it will be utilized in S&OP.

On the basis of these five criteria, Digital Twin and OSCM-related papers are selected. Figure 8 demonstrate paper selection.

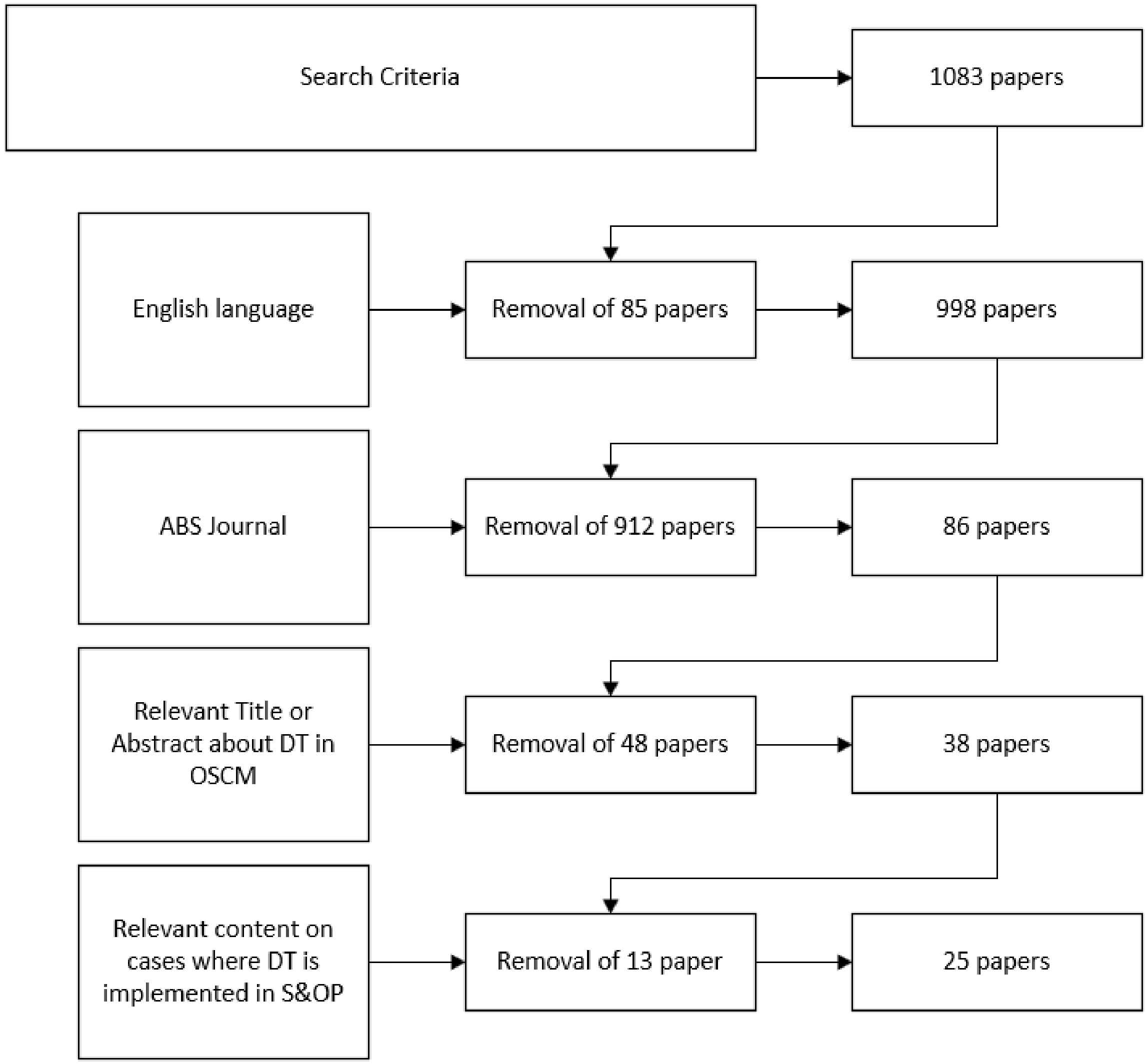

Figure 8 Paper selection process

As shown in

Figure 8, 25 publications were selected as the foundation for the literature review. These papers address a vast array of OSCM subjects, such as manufacturing, production, supply chain, and planning. The international journal of production research has published the majority of the publications. The papers that were discovered and will be utilised in the literature review are listed in

Table 2. Those papers are relevant as each of those papers show how they use DT in their respective field. Categorising all those papers, there are four context where DT is applied which are Manufacturing, Production, Supply Chain, and Planning and Management. The details of what differs between the context will be analysed in next chapter.

Table 2 Paper for literature review

No	Title	Journal Name	
Manufacturing			
1	Building a digital twin for additive manufacturing through the exploitation of blockchain: A case analysis of the aircraft industry	Computers in Industry	Mandolla et al. (2019)
2	Graduation Intelligent Manufacturing System (GiMS): an Industry 4.0 paradigm for production and operations management	Industrial Management & Data Systems	Guo et al. (2021)
3	Digital twin for smart manufacturing: a review of concepts towards a practical industrial implementation	International Journal of Computer Integrated Manufacturing	Lattanzi et al. (2021)
4	Blockchain-based digital twin sharing platform for reconfigurable socialized manufacturing resource integration	International Journal of Production Economics	Li, Li, et al. (2021)
5	Blockchain-enabled digital twin collaboration platform for heterogeneous socialized manufacturing resource management	International Journal of Production Research	Li, Fu, et al. (2021)
6	Data-driven cloud simulation architecture for automated flexible production lines: application in real smart factories	International Journal of Production Research	Wolfshorndl et al. (2020)
7	Defining a Digital Twin-based Cyber-Physical Production System for autonomous manufacturing in smart shop floors	International Journal of Production Research	Ding et al. (2019)
8	Digital twin-driven rapid individualised designing of automated flow-shop manufacturing system	International Journal of Production Research	Liu et al. (2019)
9	Knowledge-driven digital twin manufacturing cell towards intelligent manufacturing	International Journal of Production Research	Zhou et al. (2020)
10	Big data driven Hierarchical Digital Twin Predictive Remanufacturing paradigm: Architecture, control mechanism, application scenario and benefits	Journal of Cleaner Production	Yankai Wang et al. (2020)
Production			
11	Machine Learning based Digital Twin Framework for Production Optimization in Petrochemical Industry	International Journal of Information Management	Min et al. (2019)’
12	Digital twin application with horizontal coordination for reinforcement-learning-based production control in a re-entrant job shop	International Journal of	Park, Jeon, et al. (2021)

		Production Research	
13	Digital twin-driven product design framework	International Journal of Production Research	Tao et al. (2019)
14	Improved multi-fidelity simulation-based optimisation: application in a digital twin shop floor	International Journal of Production Research	Zhang et al. (2020)
15	The architectural framework of a cyber physical logistics system for digital-twin-based supply chain control	International Journal of Production Research	Park, Son, et al. (2021)
Supply chain			
16	Simulation in industry 4.0: A state-of-the-art review	Computers & Industrial Engineering	de Paula Ferreira et al. (2020)
17	Peeking into the void: Digital twins for construction site logistics	Computers in Industry	Greif et al. (2020)
18	Digital Twin-driven Supply Chain Planning	Procedia CIRP	Yuchen Wang et al. (2020)
19	A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0	Production Planning & Control	Ivanov and Dolgui (2021)
20	Food retail supply chain resilience and the COVID-19 pandemic: A digital twin-based impact analysis and improvement directions	Transportation Research Part E: Logistics and Transportation Review	Burgos and Ivanov (2021)
21	Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case	Transportation Research Part E: Logistics and Transportation Review	Ivanov (2020)
22	Digital Twin for Supply Chain Master Planning in Zero-Defect Manufacturing	Conference Paper: Advances in Information and Communication Technology	Serrano et al. (2021)
Planning and Management			
23	Integrated Platform and Digital Twin Application for Global Automotive Part Suppliers	APMS	Yang et al. (2020)
24	Warehouse management system customization and information availability in 3pl companies	Industrial Management & Data Systems	Baruffaldi et al. (2019)

25	Integrated knowledge visualization and the enterprise digital twin system for supporting strategic management decision	Management Decision	Yan et al. (2021)

3.3.4 Analysis and Synthesis

The purpose of a synthesis is to recast material from individual studies into a new or different arrangement, giving the reader with knowledge that is not obvious from reading the research in isolation (Bell, 2019; Denyer & Tranfield, 2009).

Literature review of the papers that listed in Table 2 will shows how DT is being used in different arrangement or sectors, and what are the capabilities of DT in OSCM. By synthesizing different DT definition across OSCM realms, the new idea of DT in S&OP is proposed based on literature review that will be done in next chapter with added context of S&OP from previous chapter. Later, this capability will be used to analyse the data from case study to validate and create comprehensive definition of DT in the context of S&OP.

To gather specific information that is related to these topics within these papers, a coding program can be used to simplify and create better data processing. In the process of synthesising the information from literature, information related to the objective question are extracted. It became clear that there are different definition of DT across the OSCM dimension. Then, when analysing all the DT application within different context of OSCM, it is evident that there are several advantages and capabilities that DT brings in each of the cases, which lead to second part of analysis which is to assess the DT application within S&OP and extract digital twin capabilities that can bring improvement within S&OP context.

3.4 Case Study Protocol

Yin (1994) defines a case study as a strategy to investigate an empirical topic by following a set of specified procedures, and argues that it is a good way to develop knowledge in areas where theory is scarce. Case studies are especially useful when one wants to understand a real-life phenomenon that requires contextual condition. Case studies are also particularly strong for answering how and why questions, and for in-depth exploration of phenomena (Yin, 1994). As the question and the topics itself is a novel exploratory in nature, case study is an appropriate method for this thesis. Other rationale for the case selections is presented by (Yin, 2009) . One rationale that is appropriate with this report is that it can be used to understand complex phenomenon which is S&OP in this case.

3.4.1 Choice of unit of Analysis

Yin (2009) discuss that one important step in designing case study research is defining the unit of analysis. By defining the unit of analysis in a case study, one spells out what the case is. Common units of analysis include individuals, groups, organisations or communities. They can also comprise less concrete and more abstract units such as relationships, projects, processes or even decisions (Yin, 2009). As the literature review already discuss on the DT side, then the unit of analysis in this case study will focus on the S&OP process, challenges, and what areas of S&OP that can supported by DT. Understanding those elements within the S&OP will lead to reflection on the idea of DT implementation within S&OP dimension

3.4.2 Data Collection

As this is a novel idea, the case study that is being implemented in this case would be a pharmaceutical company with supplementary knowledge from a S&OP expert and a DT expert. Both experts has different focus, where the S&OP expert will focus on giving extensive view on the areas of DT implementation within S&OP and the challenges revolves that implementation. On the other hand, DT expert focus mainly on extending the view of DT and how it can be applied practically. The main source of data for the case study and the DT and S&OP experts knowledge is semi-structured interviews.

Semi-structured interviews

In qualitative research a common data collection method is semi-structured interviews. Semi-structured interviews are conducted through an interview guideline that follows main concepts. The semi-structured interview is usually fragmented, as the interviewer may improvise follow-up questions based on the interview object's answers, and encourages space for participants' individual verbal expressions. This enables reciprocity between the interviewer and the interviewee (Kallio et al., 2016).

When conducting a semi-structured interview, the interviewers have to have a substantial level of knowledge within the research area. The questions are formulated using the interview guide. To make a high-quality interview guideline there needs to be extensive research done in the main focus areas. This is important, as the guideline offers a structure for discussions during the interview (Kallio et al., 2016).

The objective of a semi-structured interview is to explore the research area by collecting similar types of knowledge through different participants with knowledge around the subject, by presenting the interviewee with guidance on what to talk about. Advantages with semi-conducted interviews are that the interviewer can have an open mind about the concept or research area, in order to emerge concepts and theories out of the data obtained in the interviews. This approach is called the inductive approach, where the data can influence the theme of the interview (Kallio et al., 2016).

In the topics of DT in S&OP, there is still no standard or clear examples on how this should be done. Therefore, an inductive approach where the reflection of experts shape the vision on how DT should be implemented within S&OP is very important, as they have practical experience within S&OP and also DT even though in other areas such as in manufacturing or supply chain.

3.4.3 Analysing the data

In this case study, there are two ways to analyse the information that is presented in the case study. As the main topics in this report is to bring DT into the S&OP context, then the first way is using pattern matching between S&OP properties with the cases that are being presented in the literature review. The idea is to analyse all the properties of the S&OP using S&OP framework, process, and tactical planning to achieve an extensive knowledge in S&OP. Then, by looking at all the cases of DT implementation within OSCM, finding similarities within areas where DT is applied and S&OP areas resulted in ideas where DT could be implemented. Also, dissecting S&OP will help in identifying challenges and inadequate areas within S&OP. These inadequate areas will help in defining what kind of DT that is needed to improve S&OP.

The second way to analyse is by asking the experts on how they see DT implementation within S&OP. By analysing their views and the capabilities of DT, experts will give valuable information on the ideas of how and where the DT can be implemented within S&OP. By combining both ways, possibilities of DT implementation within S&OP can be identified.

3.4.4 Criteria in Social Research

When performing research, criteria for evaluating research quality should be addressed. Reliability, replicability, and validity are three crucial criteria.

Some academics claim that these notions are primarily anchored in quantitative research and have proposed alternative, but related metrics that are better appropriate for qualitative research (Bell, 2019).

However, given their established status and broad application, these notions will be discussed briefly in this thesis. Properties such as monitoring, simulation, synchronization & coordination, and data to aid in their framework development.

Reliability

Reliability is described as "consistency of a measure of a notion" (Bell, 2019), or measures done with the purpose of "minimizing errors and biases in a study" (Yin, 1994).

Given that the interviews and case study were conducted by only a team of two peoples, inter-observer consistency should be minimal. One cause of mistake and inconsistency in the case study could be the different definitions that interviewees perceived such as digital twin and the topics and elements of S&OP itself. The solution to this issue is to identify professionals with similar knowledge and experience in DT and S&OP, although from different industries. This ensures that all parties have similar knowledge and comprehension of DT and S&OP. In this case, all the interviewees background has been checked and all of them has more than 10 years of experience in their respective field, and all of them have some experiences regarding creating and implementing DT, albeit on the other context outside S&OP.

The translation of the interviews may introduce additional sources of error into the study. Even though the entire interview has been transcribed and the quotes have been translated to the best of the researcher's abilities to comprehend the interviewees' intended meaning, some intricacies may have been lost in translation.

Replicability

Yin (1994) considers replicability to be a component of reliability.

Replicability refers to whether another researcher would get the same results if the case study was repeated. In relation with reliability, in order to assess the reliability of a measure of a concept, the procedures that constitute that measure must be replicable by someone else (Bell, 2019). All those process from how the qualitative research has been done, literature review step-by-step, and how interview has been done is all described to ensure replicability

Validity

Validity is concerned with the integrity of the conclusions that are generated from a piece of research. To address validity, an effort has been made to establish operational measures appropriate to explore the issues in question by using extensive views of experts to align the conclusion from the analysis of case company.

However, it should be noted that this study makes no claims about the generalizability of its findings.

4 Understanding DT in S&OP

This chapter aims to explore the concept and definition of DT by reviewing literature of DT in OSCM that listed in previous chapter, and then a concept of DT from its definition into how it differs from similar idea such as simulation are discussed to conclude how DT should be defined in S&OP context. After that, this chapter also aims to list all the capabilities of DT in OSCM that can be leveraged into the S&OP context. This discussion based on the literature review from papers of DT in OSCM dimension and the theoretical foundation regarding the S&OP itself.

4.1 DT definition and concept in S&OP

As the purpose of this research is to implement DT in S&OP, the notion of DT in S&OP should be explained. However, according to our exhaustive research, this topic has not yet been covered in any publication. Therefore, the idea of DT must be imported from the broader S&OP environment, which is OSCM.

Based on the previous section, definition of Digital Twin that is most prominent is the one by Glassegen, which stated that "a Digital Twin is an integrated multi-physics, multiscale simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin". This is the first case in history about DT that produces a copy of a product. In this case digital twin is a copy of a hardware product.

The notion of DT definition and application has changed over the years and the context where it is being applied. Even in OSCM itself, there are four prominent context of DT application in OSCM, namely manufacturing, production, supply chain, and planning & management. By analysing how the definition of DT is constructed and why it is constructed in particular way for each of different context, the definition of DT in S&OP can be proposed by using the same structure with other context. Looking at current dimensions that are identified in OSCM, the Manufacturing process focuses on the machine process, or how machining may transform raw materials into the desired result. Production, on the other hand, focuses on utilising resources to develop values and customer-satisfying products. Supply chain focuses on the supply network and its alternatives in terms of risk disruptions or other sources. The last section is planning where it focuses on transforming the planning paradigm in order to accept and employ DT as a decision-making and planning tool. Table 3 lists some of the definitions introduced in each paper that correspond to one of these four areas.

Table 3 depicts the definition and application areas of digital twins for each industry. These two properties demonstrate how much Digital Twin has progressed since its inception, as well as how its concept and execution vary by the context or dimension between OSCM. These differences will show why DT is being used in the particular why and how DT should be used in S&OP context based on that.

Similar to the original conception of DT by Glassegen, the majority of the DT application in manufacturing articles included in this report focus on the 'hardware twin' such as shop floor as their subject (Lattanzi et al (2021) Li et al (2021) Ding et al (2019) Liu et al (2019)). This shows that manufacturing as an early adopter of DT ideas as it has the same of DT type with the original conception. However, by identifying the type of DT and the purpose of DT in each of those context, the notion of DT especially in planning (S&OP) can be proposed.

DT Type

For the purpose of DT application in a manufacturing context, the majority of papers, such as those by Latanzi, Li, and Liu, have focused on the automation of shop floors. Ding is examining another aspect of DT, which focuses on how DT might be utilised for resource management in socialised production. The focus on automation shows that the application of DT is used to increase effectiveness of system, which complement the purpose of manufacturing itself.

Similarly, some of the DT applications in production pertain to the DT of 'hardware' such as the product or plant. In contrast to the manufacturing context, the data and Twin in the production context encompass not just hardware, but also behavioural twin or data that is encased by the system. In the study by Tao et al. (2019), the DT of the product includes behavioural data such as product application by consumers, in addition to data associated with the product's physical attributes. This is apparent as the focus of production is not just to produce goods, but also to produce the value of good itself, hence the needs to analyse more intangible data such as customer behavioural data to assess the value of the product.

Table 3 Digital Twin Definition

Definition	Application	Paper	Journal
Manufacturing			
digital replica of a physical component, always connected and synchronised with it	Shop floor level	Lattanzi et al. (2021)	International Journal of Computer Integrated Manufacturing 2021 Vol. 34
a complicated software entity and integrates a knowledge-intensive digital model that virtualises and simulates the physical asset	socialised manufacturing	Li et al. (2021)	International Journal of Production Economics 2021 Vol. 240
The integration of the physical entity and virtual entity allows context-specific decisions during the entity's lifecycle.	autonomous manufacturing in shop floor	Ding et al. (2019)	International Journal of Production Research 2019 Vol. 57

DT can be viewed as a combination of modelling-based method and optimisation-based method	automation of flow in shop floor	Liu et al. (2019)	Computers & Industrial Engineering 2020
Production			Journal
DT is an advanced virtual factory that represents the heterogeneous configuration and functional units of a physical work centre and synchronises information object	Production in factory	Park, Jeon, et al. (2021)	Management Decision 2021
digital twin is an integrated multiphysics, multiscale probabilistic ultra-realistic simulation of systems or products which can mirror the life of its corresponding twin using available physical models, history data, real time data,	Product design	Tao (2019)	International Journal of Production Research
DT can be defined as an advanced virtual asset that reflects the physical asset configuration with representing the information object and functional units related to the type and instance stages of the physical asset.	reinforcement learning in production control	Park, Son, et al. (2021)	Procedia CIRP 2020
Supply Chain			
digital representation of a physical system and the seamless integration between the physical and digital spaces	General application	de Paula Ferreira et al. (2020)	Computers & Industrial Engineering 2020
integrated multiscale, Multiphysics, probabilistic simulation to mirror the lifecycle of its physical twin	Supply chain and the product	Wang et al. (2020)	Procedia CIRP 2020
digital representation of merely anything: it can be an object, product or asset	supply chain management	Marmolejo-Saucedo et al. (2020)	Procedia CIRP 2020
digital SC twin is a computerised digital SC model that represents the network state for any given moment in real time, allowing for complete end to-end SC	Supply chain disruption	Ivanov and Dolgui (2021)	Procedia CIRP 2020

visibility to improve resilience and test contingency plans – can be created.			
digital representation of an active unique product or service or production system that is characterised by certain properties or conditions used in order to analyse, understand and improve the product, product service system or production	Supply chain	Marmolejo-Saucedo et al. (2020)	Procedia CIRP 2020
Planning			
Data informed model of a physical system	Management planning system	Yan et al. (2021)	Management Decision 2021
Digital twin virtualise a system (warehouse in this case)	warehouse planning system	Baruffaldi (2019)	Industrial Management & Data Systems

Other characteristics that began to deviate from the DT of 'hardware' are on the level and scale of the twin itself. In Park Jeon's 2021 paper, the twin used is the factory's twin, which comprises shop floors and other factory-related elements. In this case, the obtained data is an aggregated data rather than the deep and specific data from or precise data previously employed in Glassegen's DT. Production dimension in this case is introducing the concept of DT to construct more macrosystems.

In the context of supply chain, macro system as a topic of DT is introduced in greater detail. Similarly, in this context, the concept of DT as the twin of 'network of hardware' is introduced, such as by Wang (2020) and Ivanov (2021). In the study by Ivanov (2021), the focus of digital twin is not on specific hardware or a set of hardware, such as that employed in the industrial industry, but rather on an integrated network of components, such as the entire supply network. The information received by DT itself is also distinct in that it is aggregated depending on how each component acts, as opposed to granular information from each component. It is a jump in modelling scale inside the DT since its conception. In addition to network-specific data, the collected information also included network related data. The emphasis of DT is also distinct. In supply chain, DT focused on analysing the performance or behaviour of the system.

On the subject of planning & management, the concept of DT of a process is introduced. In place of physical DT such as a product or product network, DT of the process is presented. To develop a DT of the process, system dynamics is used as the model for the DT such as the one that being done by (Yang et al., 2020). In this DT model, process steps are mapped into system dynamics to illustrate how each process step affects the system. In the planning and management industry, however, more conventional types of DT, like as in Barrufaldi's, are still employed. Baruffaldi employed DT of the warehouse system as the focus of his study and mapped the warehouse's behaviour based on information contained within the warehouse itself. These information systems will lead to a system for warehouse planning. This system uses forecasting planning based on historical data that gathered using sensors and other means. From this information, alternative scenario / option for handling the warehouse is presented. The purpose of DT in planning or management is to demonstrate the option and consequence of that option within the system.

DT Focus & Objective

Based on the preceding explanation, there are variations in the form and emphasis of DT application throughout OSCM. In manufacturing, the focus of DT is on the automation rather than the planning within the manufacturing. This pertains to the purpose of manufacturing, which is to provide goods. In order to improve the quantity of items delivered, automation has become a crucial aspect for improving both time and cost efficiency.

On production, the emphasis of DT application is placed on implementing intangible data to raise the value of the items. It is consistent with the purpose of production, which is to generate or add value to things. This resulted in a macrosystem approach that incorporates consumer behavioural data and information flow within the factory in addition to manufacturing data (Park, Son, et al., 2021; Tao et al., 2019). These also shows the differences between the context of manufacturing and production process. The scope of manufacturing is only on the machining process to convert raw material into the goods, whereas production focus on adding values to the product, including product manufacture. These differences shows how DT is being implemented,

On the supply chain context, DT focuses on analysing how the supply chain network responds to both internal and external inputs that impact the supply chain network. Internal input such as changes in orders, and external input such as environmental disruption (Covid) will changes the network supplies. This is evident given that the purpose of supply chain is to manage the flow of commodities. Consequently, DT is utilized to evaluate how external and internal elements may impact the flow of commodities.

On planning and management, DT focuses on providing options and demonstrating the impact of each decision. This is essential for selecting the optimal alternative in the planning and management industry.

These distinctions in objective demonstrate that DT is utilized to fulfil the objective of a certain industry. The goal of S&OP itself is to balance supply and demand. To create equilibrium between supply and demand, therefore DT definition for S&OP context need to have this objective in mind.

4.1.1 Semantic Definition of DT

Understanding that the DT concept and utilisation vary differently across those four different context in OSCM shows that the concept and definition of DT should caters to the needs in the context itself. Shifting the focus on the semantic side of DT definition, the differences and pattern on how DT definition is being built upon on each different context should shows how DT definition should be written for S&OP context.

On the semantic side of how DT is defined, there are significant distinctions between how each industry defines DT. Observations on Table 4 shows how the semantic in DT definition changes in each of the context. In the manufacturing context, the definition of DT is strongly related to the papers' primary emphasis on the application of DT. In the work of

Lattanzi et al. (2021), for instance, DT is defined as a digital replica of a physical component that is always connected and synchronized with it. In this concept, two important points that are always connected and synchronized have become the focal focus. These two essential points are the reason why DT can help leverage the problem in this article, hence this key point will become a major component of the paper. Similarly, their DT definitions in other articles pertaining to DT in manufacturing also include crucial key aspects they used.

On the subject of production, it is fairly similar to manufacturing in that the DT definition is closely tied to the case presented in the paper. An example is in the paper by Park, Jeon, et al. (2021), rather than using the terms digital representation or digital replica, they define digital twin as an advanced virtual factory, which is relevant to the case.

From a Supply Chain viewpoint, the concept of DT itself is fairly broad. One example is paper by Marmolejo-Saucedo et al. (2020), where the definition of DT in this industry is a digital representation or replica of a physical item, whether it be a product, process, or merely anything. In contrast to manufacturing, however, the definition of DT focuses on the model or asset that have diverse information, rather than a specific model that has a lot of specific set of data. On planning / management, the DT definition is also quite broad, as papers in these areas emphasize the use of DT as a novel implementation of a new paradigm of decision-making; thus, the definition is also quite loose, just as it is in the supply chain industry.

All of those differences shows that in some context such as manufacturing and production, the definition of DT is tightly related to the case that are presented in the papers, whereas in the context of supply chain and planning, DT definition are more loose and general. This indicates that DT can be both defined in a very strict way, or more loosely depends on what kind of context it is being implemented upon. The differences in the characteristic of those context that may influence on how DT is defined is on the size or boundaries of physical entities where the DT is being built in those different contexts. The size of the case within manufacturing and production are much more specific and smaller, whereas on supply chain and planning it is much more bigger and general in a sense that it uses more "macro" approach. Therefore, it can be concluded in an S&OP context, where its objectives is to create an integrated plan for the supply chain functions, it should use broader definition such as the one used in supply chain and planning context.

4.1.2 Concept of DT

Those are the differences both in the concept and the semantic of DT within those 4 different context. However, all of them still share the same key essence where virtually all definitions of DT include "digital representation of physical entity/system" as a key component. This primary characteristic of DT identifies DT as a digital entity based on physical entities that were used to represent those physical entities. These three essential elements within DT are:

- Digital entity

  The basic understanding of Digital Entity is that it should represent the physical entity. Hence, it should be able to absorb the same information and also save and behave the same as the physical entity. However, to our exhaustive research, the foundation on how and what kind of digital entity that should have built on for the digital twin is not defined yet. It very dependent on each case-by-case system. Table 4 show how each papers define their digital entity.

- Representation

Representation focus on how digital entity should represent the Physical Entity. In some papers such as by Yan et al. (2021), Park, Jeon, et al. (2021), Park, Son, et al. (2021), and Marmolejo-Saucedo et al. (2020) focuses their other point of DT definition in creating the exact digital representation of the physical entity. This implicates that there should be connection where both digital entity gain the same information as the one that physical entity get and the digital entity should behave the same way as the physical entity.

When talking about the representation, there are aspects of representation that also discussed. The first one is the connection between Digital Entity and Physical Entity, which covered by de Paula Ferreira et al. (2020), Wang et al. (2020), Lattanzi et al. (2021) and Ding et al. (2019) that stated DT should have seamless connection between a physical and virtual entity. In those papers, the seamless connection can be depicted on how the digital entity gain the data from the physical entity.

- Physical Entity

Physical entity or assets could be physical product, devices, systems, processes, places and even peoples (Yan et, al 2021). This means that Digital Twin has extended reach on what kind of Physical product/entity than can be made digital twin from it. Table 4 shows some examples of physical entity where its digital twin has been made with.

Table 4 Digital representation of Physical Entity in papers

Paper	Digital Entity	Physical Entity
Yan et al. (2021)	E-business platform and dynamic operation management (system dynamics) for the management system. System dynamics for planning the hiring process based on the workload	Management system and Hiring process.
Yuchen Wang et al. (2020)	Virtual products of the supply chain (can be broken down to each unit), such as production and inventory data, failure rate of a machine, products flow of a warehouse and amount of materials in delivery. Digital twin of the product, that contains information such as number of products for replacement, or customers' feedbacks of products in real-time to evaluate their willingness of purchase.	Supply Chain (each unit) and the product (each SKU)

Ivanov and Dolgui (2021)	Relation between each data in Supply Chain if there is disruption as input.	Process on how the DT is impacted by the disruption
Lattanzi et al. (2021)	3D models that store information such as configuration data, current states, and capabilities. Each model can interact and create result that similar to physical	Shop floor level (CNC machine and supporting tools)
Ding et al. (2019)	Logical mapping and cyber-physical mapping by modelling digital twin for each smart part to map whole production system	Shop floor consists of three CNC machine tools, two industrial robots with separate workstation buffers and the manufacturing of an impeller prototype.
Park, Son, et al. (2021)	4 kinds of Digital Twin. 1st is DT of SC from factory to manufacturer. 2nd is DT of the blanking work centre. 3rd is DT of the pressing work centre. 4th is DT of the assembly work centre.	Manufacturing SC of work centres producing automobile parts that contain machineries

To conclude the three main points of DT, DT is a digital representative equivalent of the physical entity. The physical entity has and generates massive data that feed into the digital entity in which turn digital entity to gain data that collected, stored, and processed to get an output that needed to achieve the necessary objectives. These main points should be present when defining the DT in S&OP in terms of DT concept.

4.2 Key capabilities of DT in S&OP

Some other key aspects of capabilities and foundation of DT can be found on DT definition in some papers. Paper by Ding et al. (2019) add capabilities of DT to be able to create its own decision as one of the points in the definition. Perno et al. (2022) focused on how DT is being built by using simulation and data to achieve the goal, which are real-time prediction, optimisation, monitoring, controlling, and improved decision making- Similarly, Li et al. (2021) also focus on simulation as basis foundation of DT. Marmolejo-Saucedo et al. (2020) also empower Perno et al. (2022) and Ding et al. (2019) by saying that DT is a combination of modelling based simulation and optimisation.

4.2.1 How DT is different from other technologies in OSCM context

Those papers suggest that DT is more than simulation itself, as stated in Marmolejo-Saucedo et al. (2020) that DT is a combination of simulation and optimisation. Even though Glassaegen implied DT as simulation, newer papers such as Ding et al. (2019) and Marmolejo-Saucedo et al. (2020) added more points in DT definition, so it is not only simulation but more than that, such as having capabilities to choose its own decision or doing its own optimisation.

Differences between DT and simulation tools also lies in the characteristic of simulation tools and digital twin. Paper by Wright and Davidson (2020) focused on these differences. In this paper, it is stated that simulation tool generally focuses on one single process, and the digital twin can operate with several number of simulations in order to analyse complex processes. Besides, the DT has the ability of sharing real-time data, which a regular simulation is not capable of doing. To build a digital twin it is necessary to have an actual existing object. Since it also has the ability to evolve the model as the real life twin changes and make predictions accordingly with high level of confidence. The DT can also dynamically update or adjust the model in accordance with the data. Thus, digital twins are mostly beneficial for objects that change over time (Wright & Davidson, 2020).

This paper also touched upon the topics of DT and digital representation. In many ways the DT and virtual prototypes are similar to each other, as both has the ability to test, evaluate, detect faults and predict the performance of a physical product. However, the DT has the ability to follow the whole life cycle of a physical product, while a virtual prototype can only evaluate and validate in the product design stage. DT can also integrate all the data from all the stages of a product, in regard to for example manufacturing, sales and maintenance. By integrating this data, the DT can conduct comprehensive proofing in the design stage and analyse it to eliminate potential failure. Another advantage of the DT is that it is always connected to the physical product, hence it can reflect and provide real-time data. Real-time data can be beneficial in a crisis situation or if the product has to quickly adapt to the market etc. While a regular simulation has less connection between the actual product and the virtual product, and it also only provide the ideal product that is expected. A DT can provide both an actual product and also an ideal product. By comparing and analysing both models, the differences can be found intuitively and eliminated.

4.2.2 Key capabilities of Digital Twin

To grasp the qualities of digital twin and what it can contribute to a system, the first step would be to investigate the major contribution of digital twin in the OSCM paper; then, the list of digital twin's capabilities could be obtained by categorising all the contribution.

In the context of OSCM, Digital Twin is a unique resource whose capabilities provide a firm with a competitive advantage that is valuable, scarce, difficult to copy, non-substitutable by other resources, and heterogeneously distributed among enterprises within the industry.

Several studies across various contexts, including production, manufacturing, supply chain, and supply planning, employ Digital Twin as an enabling technology to enhance their capabilities, such as e-procurement and the Digital Twin of the machine, among others. As part of Industry 4.0, Digital Twin provides numerous capabilities by introducing new technologies to the OSCM industries. According to the definition, the construction of virtual entities that imitate physical entities and the information that can travel in both directions between these two entities affords the system new capabilities. To understand what DT does and fundamental contributions of DT to a system, Table 5 shows DT application and what DT gives to a system. From the table the capabilities of DT can be shown and those capabilities that can help planning (S&OP) can be identified.

Table 5 Key focus in DT application in OSCM

Paper	Different context within OSCM	DT of	DT application	DT key Focus
Lattanzi et al. (2021)	Manufacturing	CNC machine and supporting tools within shop floor level	automatic scheduling in the shop floor	Assess the condition and act based on prediction
Ding et al. (2019)	Manufacturing	Machinery within Shop floor	Automatic reconfiguring by connecting all the component	Autonomous manufacturing
Park, Son, et al. (2021)	Manufacturing	Automobile factory machineries	Synchronisation of each machine within shop floor using cyber-physical system	Resilience in manufacturing
Luo et al. (2021)	Manufacturing	Manufacturing resources	Provide planning and scheduling for dynamic resource allocation by using simulation to forecast the dynamic resources	Simulation and forecast
Guo et al. (2021) t	Manufacturing	Manufacturing process	Basis for GIMS framework	Information visibility and traceability
Liu et al. (2019)	Manufacturing	shop floor	As a foundation of DT-driven rapid individualised design of AFMS	Simulation and prediction

Tao et al. (2019)	Production	Product	Virtual product that coevolve with physical product	Visibility of data throughout lifecycle
Park, Son, et al. (2021)	Production	Production process (from manufacturing to supply chain)	Simulate production process for visualisation tools for planner to synchronise the plan	Visibility of data throughout production process
Yang et al. (2020)	Supply chain	Global supply chain of a company	Tool to fed real-time data to manufacturing process	Real-time data gathering and visibility
Burgos and Ivanov (2021)	Supply chain	Supply network of a product	Simulate and optimise best network chain	Real-time data gathering and simulation
Yuchen Wang et al. (2020)	Supply Chain	Supply Chain (each unit) and the product (each SKU)	Predictive optimisation of supply chain planning by using real-time data	Reduce lead times, improve forecast accuracy and planning verification within supply chain planning
Ivanov and Dolgui (2021)	Supply Chain	The impact of disruption within supply chain	Predicting alternative supply network topology for disruption	Increase SC resilience through faster and more reliable recognition of disruption with real-time data analysis
Baruffaldi et al. (2019)	Planning	Warehouse system	Foundation in DST to combat current WMS problem by providing data and simulated scenarios.	Real-time data gathering and simulation
Yan et al. (2021)	Planning	Management dynamic system	Enabling real time data analysis and scenario analysis in decision	Provides dynamic capabilities within management system

			support tool for complex decision such as issuing job offers	

On the basis of these essential contributions, the essential key focus is also shown. It is clear from looking at Table 5. that the key focus of DT are many, and they have a specific application in each of the study scenarios.

There are several recurring key-focus that has been used in the Table 5. In some of those papers, there are different key focus that is being used simultaneously. It is however, clearly shows what are the key-focus on DT application within OSCM. Those key focus shows the capabilities of DT that are highly graded and used extensively in OSCM. Those key capabilities are the main reason why they are adopting DT. Hence, it is worthwhile to bring those key capabilities into S&OP. Table 6 shows those key capabilities

Table 6 Key capabilities of DT in OSCM

Proposed Capabilities	Papers Related
Prediction & Forecasting	Yankai Wang et al. (2020), Luo et al. (2021) , Liu et al. (2019), Ivanov and Dolgui (2021), Burgos and Ivanov (2021)s
Real-time Communication	Li, Li, et al. (2021), Li, Li, et al. (2021), Guo et al. (2021)
Transparency/visibility and tracking /traceability	Yang et al. (2020), Baruffaldi et al. (2019), Tao et al. (2019)
Real-time data analysis	Yan et al. (2021) Yuchen Wang et al. (2020)

Based from all the key contribution in each of the cases presented in Table 6, the key capabilities of DT and the papers that utilise these features as the primary contributor to their system are listed. There are five primary important capabilities of digital twin, which are:

- **Prediction and forecasting,** A large number of mentioned papers from the context of manufacturing into supply chain under OSCM used this capabilities in their paper. In manufacturing, forecasting is performed on paper by a (big data-driven) system that uses real-time data of the manufacturing environment and the market to make decisions and predictions for the initial configuration of a smart environment and the quality of each remanufacturing on a cloud platform using a deep-learning model. Other paper by (DT-driven rapid) also attempts to predict the result by using simulation in their AFMS framework with bi-level programming to simulate whether the static design (e.g., assembly solution, control scheme) can meet the target requirement; if not, the values within the static design are adjusted.

In supply chain, the paper by (a digital supply chain twin rfor managing disruption) utilises the forecasting capability of DT by developing a Decision Support System (DSS) using DT of the network topologies and feeding the disruption risk data as supply chain disruption risk to forecast the alternative supply chain route and estimated time of arrival. Likewise, (food retail supply chain resilience) attempts to mimic alternative network routes in the event of outages. This study also develops DT for network topologies made up of consumer locations, distribution centres, factories, and suppliers. This study emphasises the importance of network flexibility inside each component of DT, such as the customers or the factories.

- **Real-time data gathering and communication,** is also other capabilities that highly sought in DT implementation. On paper by (defining digital twin based) creating Physical Shop Floor (PSF), Cyber Shop Floor (CSF), and network connectivity between the two, they created the DT system. In PSF, they use intelligent components that understand the manufacturing sequence, including the type of machine required and the production progress. Those members will interact proactively with other PSF members to make initial decisions. This PSF employs RFID tags as a tool. Then, these data are transmitted to CSF, where the plant model is created, and analytics for reconfiguring the production process based on these real-time data can be created.

Other paper by (GIMS) employs DT by constructing three layers: physical layer, cloud space layer, and digital twin data layer that connects physical and cloud space. In physical space, they employ IoT technologies (e.g., radio frequency, RFID) to transmit and map the manufacturing status of objects (e.g., ID, attribute, status, and services) in real time. Then, these data are mapped to digital tickets in the Digital twin data layer, which will serve as the foundation for job task service, setup task service, and logistic service performed by managers and onsite operators.

- **Visibility and traceability,** is also other important capabilities of DT. On paper by (integrated platform and digital twin application), they construct a virtual factory model that is linked to the data of operators and processes collected in real time at the production site. These factories are linked to operator information collected on-site and provide visibility into all data and activities occurring on-site. This visibility enables them to design a system capable of predicting a range of problems and evaluating potential solutions by tying production management algorithms to these data. Similarly, paper by (warehouse management) uses DT to collect all the data on storage information and process to gain visibility on the warehouse detail, which is then utilised to create an alternative management scenario through simulation.

Another paper by (digital twin-driven product design) collects all the attributes, behaviour, and performance of the physical entities during manufacturing, use, maintenance, repair, and disposal. The visibility of these data will be employed to reflect and map the physical entity, and a subset of physical and virtual data can be obtained. Then, throughout the design and production phases, the parameter data from the virtual entities will be transmitted to the production line, and the virtual models will be transformed into actual physical items.

- **Real-time data analysis.** Even though intuitively both capabilities of forecasting and real-time data gathering resulted in real-time data analysis, but there is a paper that explicitly uses these capabilities in their system. In paper by (integrated knowledge visualisation), models are constructed using the system dynamics (SD) modelling technique and digital twin. The SD creates a process-based input and output system, and the enterprise digital twin system will be a clone of the organisation's assets, processes, people, and systems. These replicas are presented as SD models for real-time analysis of knowledge development visualisation and weekly decision-making.

Other paper by (data-driven supply chain) employs DT as a real-time data analysis by employing DT as a tool to access data for the planning and employing virtual modelling and simulation for analysis in the planning, from demand forecasting, aggregate planning, and inventory planning. On the aggregate planning, for instance, they use real-time production levels and real-time inventory levels gathered by DT to generate supply planning, and virtual modelling and simulation will assist with this supply planning.

All in all, all those four capabilities are key capabilities that are highly sought in DT. These capabilities will always work hand-in-hand and interconnected as every DT application will help the system to gain those four capabilities. However, the focus and to what extent the application of those four capabilities are decided by the creator of those DT systems.

4.2.3 How DT capabilities support S&OP

List all the capabilities, and show similarities on the application with some of the properties within S&OP

Listed from Table 6, there are 4 key capabilities that being implemented within the domain of OSCM, which are real time data gathering and communication, visibility and traceability, and real-time data analysis. To understand how the capabilities can support the current S&OP, is by looking at the potential of each capabilities within S&OP dimension.

Prediction and Forecasting. In OSCM dimension, prediction and forecasting are being used to predict the next input for the system itself such as paper by (big data-driven) where the prediction is used to predict the next input for remanufacturing process. Other application of prediction and forecasting that are more common are to forecast the result of a choice within a system and help in decision making within a system. Some of the papers that used this application is paper by Ivanov and Dolgui (2021), where it is used to predict alternative supply route in case of disruption, and similarly by Burgos and Ivanov (2021) to predict alternative supply route in case of outage.

These two type of DT application shows that DT is applied in order to increase the response time and decision-making under uncertainties. In general, there are some decision that is being made in S&OP such as decisions on how much demand that needs to be fulfilled. That decision will be affected by uncertainties such as market uncertainties or other external factors. This shows direct possibility on how DT capabilities can help in S&OP. However, to know practical areas or detail on how these capabilities can help, a case study within S&OP is needed to identify the specific problem and how it relates to the uncertainties.

Real-time data gathering and communication. In OSCM dimension, these capabilities are used for real-time reconfiguration such as in paper by Ding et al. (2019) , where it used these capabilities to real-time reconfiguring of the Physical shoo floor to gain higher efficiency. Another application is by Guo et al. (2021) where the data in manufacturing are procured in real-time as visualisation aid for managers and personnel to monitor and create decisions accordingly.

Looking at the DT application in those two cases, the reason why real-time data gathering is needed is to be a visualisation aid for the decision making and to oversee the system itself. As the reason why real-time oversee is needed, it depends on the case itself. In the

S&OP, one instance where real-time visualisation is needed is when tracking critical item or component for the product itself. More discussion and extensive views on S&OP are needed for in-depth discussion.

Visibility and traceability. In OSCM dimension, Visibility and Traceability are used for system integration, where each of the actor or component within the system can access all the data in the system itself. This will lead to a consistent data throughout the system and integration between each component is achieved

As S&OP objective is to create integration between both horizontal and vertical coordination between function in the company, this visibility and traceability would be one of the most important aspect within DT that helps S&OP in achieving its objective. There are many scenarios where visibility is important within S&OP, for instances as when the sales team can see the production capabilities of production team, so they can manage how many orders that they want to accept based on that. Other example is by having external supplier visibility, S&OP team can estimate both production cost and produced units by production teams. There are a lot of application in visibility inside S&OP itself that can be known later on.

Real-time data analysis. This capability is in a way one step further from other capabilities which are real-time data gathering and communication. In cases such as by Yan et al. (2021) and Baruffaldi et al. (2019), it is being used as decision support tools, where the result of data analysis can aid in decision making. One reason why this is needed is that the data is not easily digestible by the planner or the implication of the data is not clearly visible, as it is the case in paper by Yan et al. (2021) where it uses DT of system dynamics for the decision making. Data and consequences in system dynamics are not apparent as it might follow long logical rules before it resulted in something within the system. This led to a difficulties hence in-house analysis is needed.

The potential of this capabilities is huge as it is a step further, where DT also has ability to analyse the data that it gathered for the users. However, the complexity of creating this DT will be apparent as DT is not just mimicking, but has a specific set of algorithm to assess the data and give results to the users. The application is also a challenge as the areas where the DT is applied need to be properly defined so the data analysis will resulted in right data. Those challenges presented will create further discussion in what kind of DT and what kind of capabilities it should have later on in this report.

5 Study Case

There are 3 objective in this case study. The first one is to explore S&OP so extensive view can be achieved for finding the challenges and areas where DT can be implemented to. The second part is to gain insight on how DT can affect S&OP. lastly, DT experts will give information related to the fundamental of DT and how ST can be implemented in any system. Based from all those knowledge, How DT should be implemented can be achieved.

5.1 Case Company Introduction

To observe how current S&OP is being implemented, IT technology that has been used, and the current view of DT on practitioner, this paper has chosen to look into one case company.

5.1.1 Introduction

Company A is a global supplier of technology and services that promote and expedite the research and production of therapeutics. The company is a business-to-business (B2B) pharmaceutical company that primarily sells to other pharmaceutical companies, as opposed to consumers. Therefore, they acquire large order accounts and clients such as Johnson & Johnson, Pfizer, AstraZeneca, and Moderna. Their business can be divided into two; standardized products and customized products. Consequently, the variety of the products is context-dependent. The corporation operates in forty countries throughout Europe, Asia, North and South America, and the Middle East. The interviewed business was located in New York, United States.

5.1.2 Pillars

The company's business is defined in two different pillars. The differences in the pillar is explained in the subsections. However, this case study will focus on pillar one.

Pillar One

Pillar one consist of the products that the business owns and sell. The company owns the patent for the formula and these products are produced as standard products. The standard products are well-known around the country, and the costumers knows that they can only buy that specific product from this company, as it is trademarked. Pillar one closely resembles fast-paced consumer goods, and therefore it is relatively stable and easier to predict demand. The focus on pillar one is to sell the same standardized products to many customers. The stability of the standardized products is high. If the formula does not change or a competitor takes over, the life-cycle is typically five years. The life-cycle of this pillar is quite stable, as it is easier to predict.

Pillar Two

Pillar two, on the other hand, primarily focuses on customized products. In majority of cases the company does not own the formula; instead, it obtains the customer's specifications and produces the product accordingly. In other circumstances, the company owns the formula, but the large pharma companies may wish to alter a portion of it; the final product will then be modified accordingly. Typically, the customers do not have the ability to produce it themselves, so they order it from company A, which then purchases the raw ingredients, manufactures the final goods, and ships them. However, the focus on pillar two is a specific customer and customized products according to the specific customer. This pillar's life-cycle is highly unpredictable, as it depends heavily on the customer. However, when a customer wishes to adapt a formula that Company A owns, the company A has slightly greater control over the pricing and the product's lifespan.

5.1.3 Customer

As stated in the introduction, Company A is a business-to-business, meaning they sell their products to other businesses and not directly to consumers. Customers are primarily other pharmaceutical corporations, but also businesses from other industries. The customers are divided into four groups:

1. Big Pharmaceutical companies:
   Johnson & Johnson, Pfizer, AstraZeneca, and Moderna are the major pharmaceutical corporations. These customers primarily desire medicines to be manufactured from Company A, in order to sell to consumers.
2. Life Sciences companies:
   Traditionally, Life Sciences companies operates in pharmaceuticals, biotechnology and medical device areas. These companies are not interested in the manufactured final medications, however they are interested in the manufactured technologies or devices that goes into medicines.
3. Research and Development facilities:
   These facilities specialize in investigating and applies research on products. The customers are usually smaller labs that might not commercialize things, but are only into research and development.
4. Universities:
   Generally, universities do not require vast quantities of items because their laboratories require just modest amounts. Regardless, this is a very important client for Company A, despite the institutions' little revenue. If the University suddenly discovers something significant, they will require company A for the 10 to 15-year of product life- cycle. Many of Company A's large customers began in a small lab or universities, and as they grew, so did Company A.

5.2 S&OP Process of Case Study

The second aspect in understanding S&OP within a company is to understand its process. By understanding its S&OP Process, all the detail of how S&OP is being done would be laid out, and further discussion can be carried out. Therefore, it would be a great benefit to show S&OP process of each company and the S&OP process that used in literature

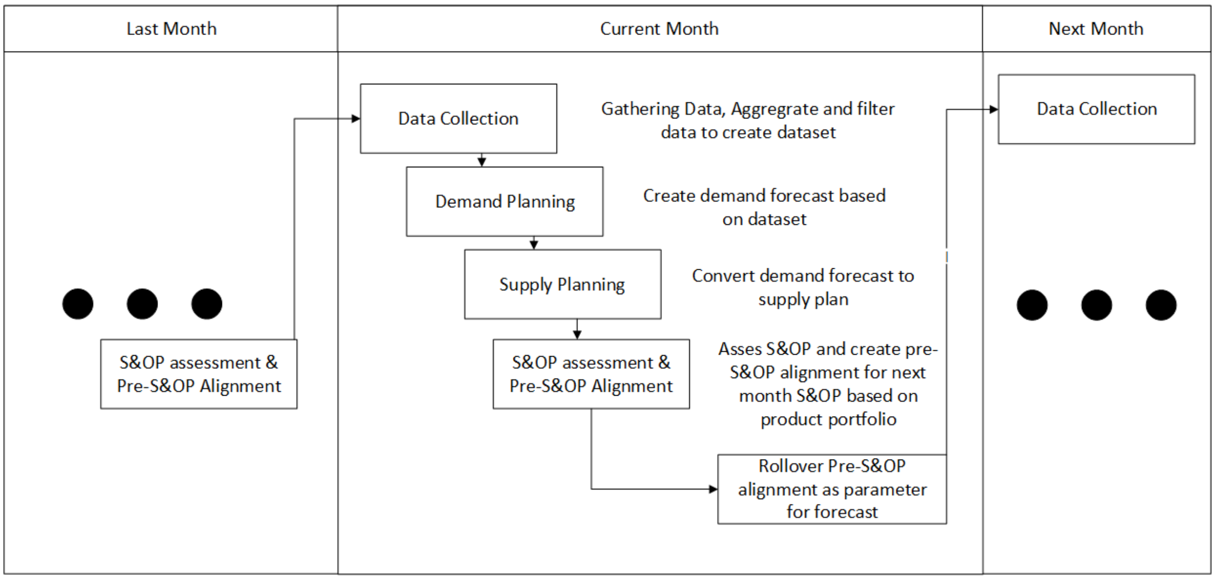

Figure 9 S&OP Process

Figure 9 shows the S&OP process for the Company A, The first week started as forecast planning week. In this week, the forecast plan is created based the information from each sales team members and the historical data. Then in week 2, the forecast planning is being floored to each function that connected to demand planning in order to be finalised and updated as consensus demand plan. In week 3, the demand plan is being reviewed between the demand planner and factory managers. All the factory managers will have discussion on how to create a supply plan by dividing the demand between each factory managers by assessing both demand and factory data such as geographical location, product flow, production and transportation costs and also the capacity and inventory of the factory and warehouse. This discussion will result in supply inventory plan is being finalised. Lastly, the executive meeting will be held to inform all the executives and stakeholders in regards to S&OP plans.

5.3 S&OP decision making

In the preceding section, the S&OP process of the company is described. As the goal of our investigation into corporate S&OP is to determine how DT may optimize S&OP in a company, it is necessary to have a comprehensive understanding of decision making inside S&OP, as one of the capabilities of DT is to help decision making.

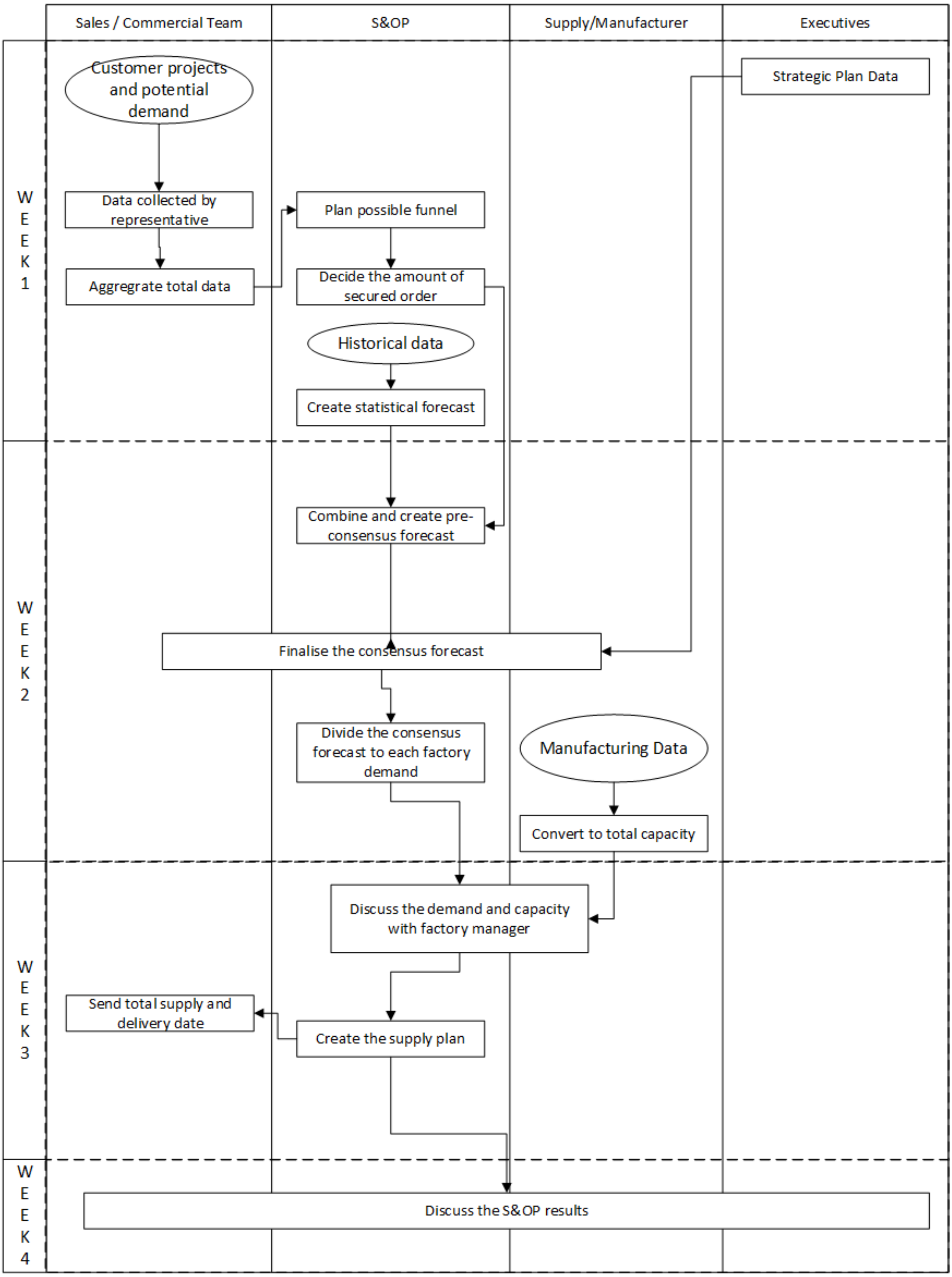

Figure 10 S&OP decision making process

Figure 10 depicts the decision-making and data flow in the S&OP process. In the first week, the sales representative or commercial team collects data pertaining to upcoming customer initiatives, which may include information about potential demand.

Then, the commercial team manager will collect these data, and the S&OP team will develop a funnel from these data. The funnel contains the dimensions of potential demand, where S&OP teams separate potential demand into demand quantity and demand volatility. One example is high-stable and low volume. This shows that the demand is stable, which indicates that there will not be many variations in the value, and that the demand volume is small relative to other demand. On the other hand, irregular and high volume indicate that there is a great likelihood that the demand quantity will change, and that the demand quantity will be high.

On the basis of this data, the S&OP teams can decide whether to simply use the data and monitor it from the commercial team, or to further communicate with the customer and commercial team to secure the order.

In parallel, S&OP teams initiated the development of a statistical projection based on previous data. The outcome of these statistical forecasts serves as the basis for the consensus forecast. Then, these secured orders from each individual customer will replace the statistical forecast information for that customer.

This indicates that the purpose of statistical forecasting is to close the gap between the known customer demand and the unknown demand. This data is typically accessible by the end of the first week and is referred to as pre-consensus forecast data.

At the beginning of week 2, the commercial team and the production team will analyse pre-consensus prediction data in relation to strategic plan information from executives. This conversation will resolve disagreements and produce final forecast data based on a consensus. Then, each factory's demand will be derived from the consensus data. This category is based on the capacity expertise of the S&OP team.

Each demand will be negotiated with factory managers in order to match it with the factory's capability. S&OP team will then divide the demand based on each of the factory in the same region as the demand. However, if the demand exceeds the amount of maximum capacity in that factory, then S&OP team will calculate which neighbouring factory can supply the demand with the cheapest cost compared to other. If the cost is exceeding the maximum cost that has already been determined, then S&OP teams will discuss with the customer to decide whether to add more payment, delay the products to next month, or cancel that amount of order. This conversation will result in a supply plan, and then the data regarding how much demand will be given to each client together with the delivery date will be sent to each customer. After the S&OP process has concluded, the S&OP outcomes will be discussed.

5.4 S&OP data management

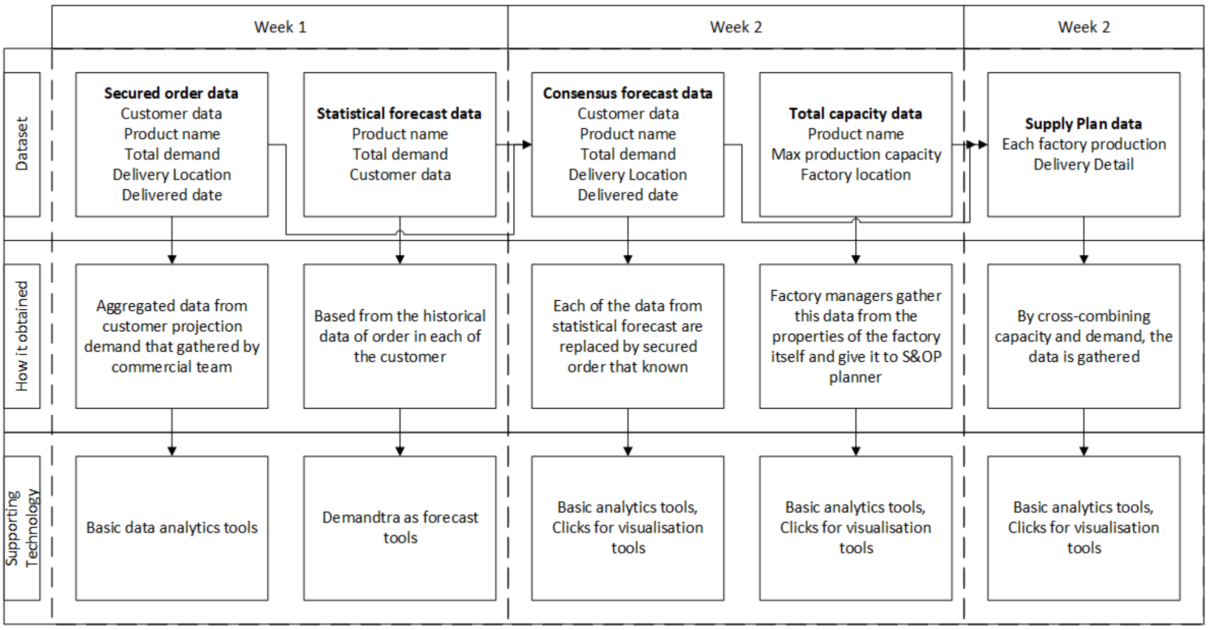

Figure 11 S&OP Data management

As decision-making has already been covered in a prior section. In this section, the data and supporting technology will be investigated. Extensive examination of this area will result in greater clarity regarding how decisions are made and what types of data are utilized.

Figure 11 shows data management in the S&OP process. In week 1, the sales teams' secured order data are extracted and used as the basis for market data. This information specifies for each order who the customer is, what the product is, how much product is required, when the product should be sent, and where it should be sent. S&OP teams derive this information from the client demand projections provided by the sales team. S&OP teams analyse the demand and, using a funnel method and basic data analytic tools, establish the order quantity.

Statistical forecasts for this month's demand are generated using historical information from past orders. Using demandtra as a tool, statistical forecast data are generated and will serve as the foundation for consensus data. This data simply includes the quantity and identity of demand for each commodity.

In week 2, statistical forecast data are used as a starting point to generate consensus forecast data. This information represents the quantity of demand for each product from each customer. Then, these statistics data are replaced with consumers' encrypted order information. This substitution substitutes the majority of statistical data. It produced consensus data containing protected order information for known customers and predictions for the remaining clients. Typically, small clients consist of university/hospital laboratories. This forecast consensus data is divided by two, pre-consensus and final consensus data. Discussion with other function is being done using clicks as visualisation tool and the pre-consensus data is changed to final consensus data when every function agrees to it.

Each factory manager is independently collecting factory properties data to determine the highest production capacity they can manage this month for each product they manufacture. This data will then be shared to the S&OP team so they may use it for next week's supply plan data. Typically, they send information on the products they manufacture and their maximum production capacity.

In week 4, the S&OP team creates supply plan data by merging demand from consensus prediction data with total capacity data from each factory manager. The S&OP team will then divide the demand by factory within the same region as the demand. If demand exceeds capacity, S&OP teams will develop a plan to accommodate the excess demand. This procedure generates supply plan data with production and delivery information for each product

5.5 S&OP Framework Company A

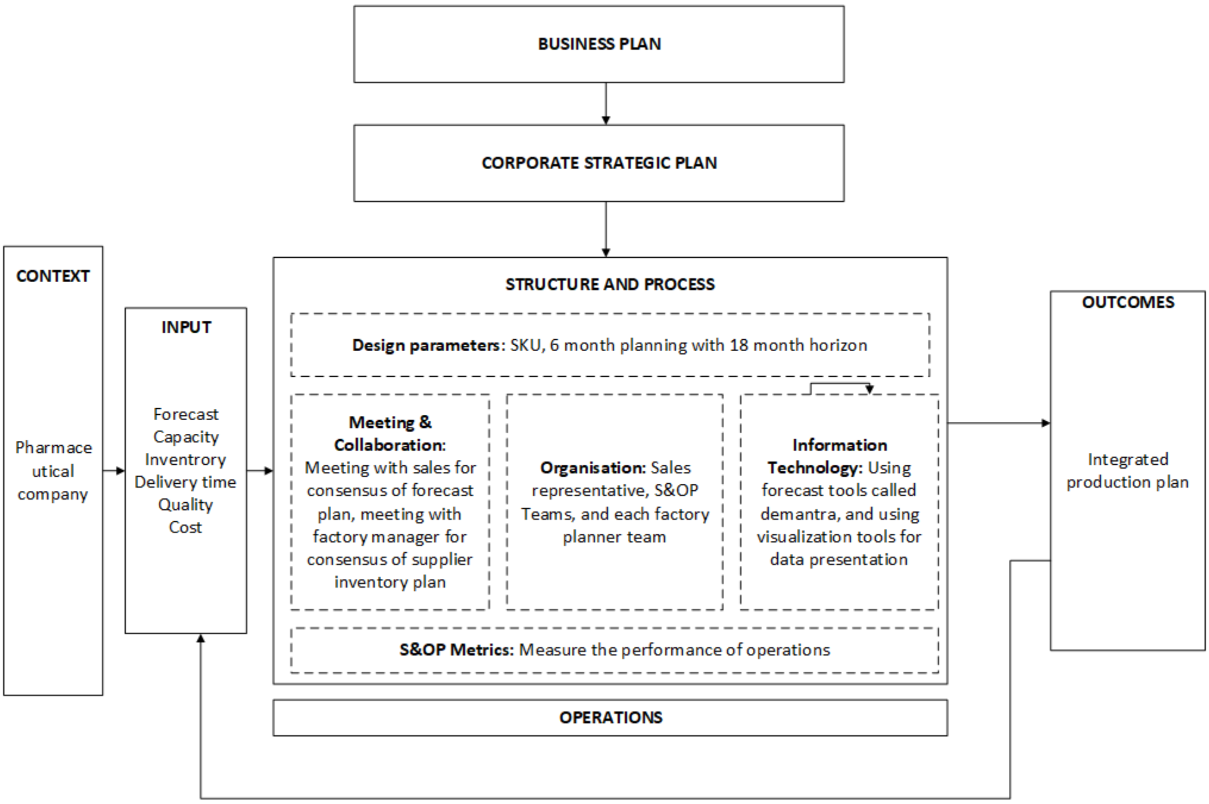

Figure 12 S&OP Framework of Company A

In a process to understand the characteristic and the properties of S&OP process within the companies, and S&OP framework need to be identified. From the context where it operates, up to the result of the S&OP itself.

Figure 12 shows the S&OP framework of Company A where some of its characteristic has been shown

5.5.1 Context

In this instance, the company operates in the pharmaceutical industry, supplying other enterprises with semi-finished goods. This business operates as a B2B enterprise, maintaining tight ties with its clients. It leads to customer projects as one of the context, as demand from the quantity to the type of product is highly dependent on the customer, and customer projects within the pharmaceutical sector are one of the context's most essential aspects.

On the internal side, the firm's capabilities, such as its maximum production capacity, were significant factors. As a B2B organization, the sales representative's relationship with the customer is crucial. Referring to other contexts involving client projects, customers typically have projects for which they require a supply of products, and the supply will be distributed amongst the suppliers.

If the relationship between the company and the sales representative is positive, the proportion of products supplied by the company will increase.

5.5.2 Input

The input that is used to create the forecast for the market are historical demand and planned demand from each sales representative that has close connection with the procurement team of the buyer. In the supply side, capacity and inventory became the main vocal for the parameters that need to be assessed. companies need to assess the capabilities of their factories and warehouse. Also, after combining both demand and sales, the company will check whether the demand can be supplied with the effective cost and quality that is needed. Therefore, even though delivery time, quality, and cost are also important input, the crucial input are forecast data, capacity of the firms, and inventory availability within the firms.

Design Parameter

The planning horizon that used is 18 months that trickles down to 6 months for a more detailed plan. They use SKU as basis to create categories for their planning

Meeting and Collaboration

In each week, there are different meeting based on the state of the S&OP process within the company. These meeting are described below:

- Meeting with the sales team, where the objective of this meeting is to create consensus for a forecast plan. In this meeting, all the sales team present the demand that they got from the client's procurement team. All this demand will help shape the forecast plan alongside the historical data from previous demand and create a consensus forecast plan that accepted by all sales team and stakeholder
- Meeting with factory manager, where after the forecast plan already finalised, all factory managers discuss the visibility of carrying out the demand from the forecast plan. Based on the availability of each factories, geographical locations, and warehouse, the forecast plan will be transformed into supplier inventory plan.

Organisation

The S&OP function is incorporated into a team called demand planner. This team includes sales team and the analyst for creating the forecast plan. They work closely with other stakeholder such as factory managers finances, and also having a meeting with executives once a month.

Information Technology

There are some application that used in this company. For creating the forecast plan, they rely on the forecast tool called demandtra by Oracle. This tools used historical data and inputted data to create the forecast plan.

To visualise the data whether it is forecast for demand planning or factory data for supply planning, they use Click as visualisation tools.

Planning objective and metrics

Overall planning objective is to optimise production and sales

S&OP Metrics

There are only two parameters utilised to evaluate the S&OP within the companies. The first is the precision of the demand forecast. This is determined by computing the difference between the predicted total quantity of product required and the actual quantity of product required by customers. The second factor is the performance of each factory, or the amount of production that each supplier can provide for its neighbouring customers. Typically, the acceptable quantity is 95 percent, which means that each factory can meet 95 percent of the demand from nearby consumers, with the remaining 5 percent being met by other factories within the required budget

Outcome

The outcome of planning process is integration plan between demand, production, and sales.

5.6 Challenges in the conventional S&OP

According to the S&OP manager at company A, the accuracy of their predictions is one of their greatest S&OP issues. As sales and operations management is centred on balancing demand and supply, forecasting is the most important aspect in achieving this. Any incorrect decisions will result in the wasteful procurement of raw materials and the production of final goods that will wind up in the inventory despite not being required. Consequently, as the S&OP manager summarized, their job is to:

"My flock of challenge, or I think most of the S&OP people challenge, would be to make sure that it is minimum."

In order to comprehend how forecasting influences S&OP, the forecast-method in company A's demand planning is described upon in the next section.

5.6.1 Forecasting

The S&OP manager explains that there are mainly three ways of doing the forecasting in their company. One is based on mathematical numbers, another is knowledge-based predictions, the third is a combination of both.

The S&OP manager usually start with examining the historical prediction. Future forecasts will be generated by a statistical engine using data from the previous 5 to 10 years. The engine develops a future projection based on historical data, inflation growth, and economic factors. The future forecast is anticipated by adding all the numbers. Therefore, this type of forecasting is purely mathematical.

Sometimes the S&OP manager makes decisions on forecasting based on knowledge from various sources, that are not particularly based on scientific research. The sources can be through specific information, such as the growth of certain geographies or if there is a new product launch, the marketing campaign has to be considered. These sources are more through common knowledge, experience and through knowledge-sharing with other relevant sources. This will be further discussed in chapter 5.1.6.3

Usually when examining the forecast and making the decisions based on the forecast both the mathematical forecast and the experience-based forecast is incorporated and analysed. A combination of both the forecasts are then used in order to decide the demand. Depending on the customer type, one of these three types are used. In the next section the different types of customer and the type of forecast method is showcased

5.6.2 Customers and forecast method

Predictions can be based on data, the S&OP manager's expertise, or a combination of the two. The S&OP manager decides on the prediction type based on the following four buckets:

High stable and high volumes: The engine estimates the forecast, while the S&OP manager monitors it. This type is particularly essential; the entire cost of the decision will depend heavily on those with high stability and high volume, since they represent around 80% of the business's revenue.

High stable and low volumes: Here, the S&OP manager does not intervene, leaving the decision to the mathematical engine. These cases are of minimal importance, thus the management does not spend effort on it.

Irregular and low volume: Due to the fact that this is of low value and difficult to forecast. It will need a great deal of effort to determine, the management does not spend time on this as it will not provide much value. There, this is based on the mathematical engine alone.

Irregular and high volume: Here, the S&OP manager spends the most of his time. These cases are extremely difficult to predict because they vary at random. In addition, the volume is very high, therefore any change in inaccuracy would result in costly decisions. In this case both S&OP manager's expertise and the mathematical engines are used.

5.6.3 Factors that impact the forecast

Now that the forecasting methods are explored, some of the factors that impacts the forecast needs to be explored. As explained in the section about context in the S&OP framework, there are both internal and external factors that impacts the forecasts and the decisions that are being made.

External factors:

External factors are factors that are outside the organization, and will impact the success of the business. These factors can be hard to control, however it is possible to react to them easier with accurate forecasting. Hence, it is important for Company A to know what the external factors are, and consider them in the forecast analysis.

Customers is one of the external factors. It is necessary to look at what they are doing, what their actual need is. It is basically necessary to look at what the project that the customers are working on, and which of these projects will create a pipeline for the company A.

Competitors is another external factor. It is necessary to look into what the competitors are capable of doing and estimate how directly in line of competition they are in comparison to Company A. Other factors that has to be taken into account are the competitors installed capacity, how fast can they ramp things up? The agility of the competitor and their price points are also considered, as they are competing in the same market as company A. The competitor impact how much business the company A will get.

The Environment is the most important external factor. The environment includes the framework of the company, legal issues, political aspects, socio-political, technological and geographical. For instance, if there is a new product launch, there might be a marketing campaign that' running, which can push the sales up. Factors like these are important to take into consideration, as this could enhance or decrease as it is dependent on how people receive it. Another example, is that the S&OP manger has for instance reduced the forecast for Europe significantly, because of the war in Ukraine. All these factors are important points to look at in the forecast.

Internal factors:

Just like external factors, internal factors in the organization can also affect the forecasting.

Technological capabilities are one of the internal factors in company A. Technological capability is usually a company's ability to upgrade knowledge and develop new processes. In company A, it is the ability to meet customers demand.

Installed capacity is another internal factor. If a customer wants 10 products now and 10, 000 products tomorrow, how quickly can the company adapt in regards to capacity, for instance.

There are also many soft factors like sales team or commercial team. The commercial team can pitch and sale converter opportunities, and it depends on how well this is done. The S&OP calls it demand shaping techniques, where marketing activities like offering discounts are accounted for. These kinds of activities can attract customers and can ultimately increase the demand, which are decided inside the company.

5.7 Analysis of the companies and its S&OP

5.7.1 Analysis on the company and the industry

There are essential characteristics in the firm introduction. These major characteristics are their pharmaceutical competence, their B2B business strategy, and the size versus scope of their operations. As pharmaceutical fields are vital and closely tied to human lives, there are many restrictions or rules within the industry, particularly when a new product will be introduced. Before being mass-produced, new goods such as vaccines and serums must undergo a series of clinical studies. This company works as supplier for the ingredients in that products, hence it is working in B2B strategy. It means the demand is low during these test times. However, after the product hits the market, demand will climb exponentially. There is also the potential that the product will fail the test and be scrapped.

This is why this company has two pillars: the first pillar is for products that have already hit the market, and the second pillar is for materials that customers will use to create new products. As demand for the second pillar is typically low and highly configurable, the S&OP is only applied to the first pillar. As the company operates as a business-to-business entity, customer relationships are crucial. There are four customer groups that are being determined. In certain businesses, particularly if the company is B2B, the demand is not effectively dispersed within the customer group. The first group, which consists of large pharmaceutical businesses, contributes significantly to the company's demand. This has resulted in a demand that is controlled by important customers, meaning that changes in the demand of these major clients would impact the whole demand of the companies. In S&OP, it is essential to forecast and communicate with these critical clients. Intriguingly, despite the fact that the company's primary clients are large corporations, as described in the preceding section, universities also have a substantial, albeit delayed, impact on demand. Due to the fact that most large corporations began as tiny labs in colleges, early engagement and cooperation with this small lab will be extremely advantageous in the future.

Analysis on company SOP Process

In order to meet the needs of both large and small clients, the S&OP process will be challenged by a company's need to analyse both large and small clients properly. Despite the challenges that this company will experience due to the characteristics of the industry and the consumer, the S&OP process in this organisation does not differ much. This company's S&OP procedure was extremely similar to the one described in the literature. Data collection, demand planning, supply planning, and executive meetings comprise the four phases. This organisation follows the standard S&OP approach, where During data collection, companies collect information from both their commercial teams and historical records. Then, in demand planning, the collected data are processed and the demand plan is developed. In the supply plan, the company's suppliers' capacities and methods for satisfying demand are considered. The supply plan is designed to incorporate information on how to meet the demand for supplied items. Finally, the results of the S&OP will be addressed with company executives.

Analysis on company S&OP decision making and planning

In order to learn more about the S&OP process and how the changes affect the S&OP process, it is necessary to examine the S&OP process's decision making and planning in greater detail. The S&OP teams develop a funnel that is subdivided into four buckets in order to address client group-related problems. This decision is extremely important because it influences the entire demand. The next option that is highly tied to this is the quantity of each customer's secured order. Currently, the S&OP team is the one who formed that division, and the S&OP team is also the one that takes the proper action in relation to each bucket group. This decision is one of the most important in the decision-making process. Another crucial issue is determining the supply plan. This is due to the fact that the S&OP team manually divides the demand and calculates the solution to the excess demand problem. These two vital decisions are the most important within the S&OP process. Improvement regarding these two decisions will have a substantial effect on the S&OP of the organisation.

Analysis on company S&OP data management and Supporting technology

To comprehend the complexity of the issue posed by these two decisions, it is necessary to comprehend every key factor surrounding them, such as the type of data, how it is used, and the supporting technologies that aid in decision making. Understanding these data will result in an analysis that aids in enhancing these two crucial decisions. For the first decision, which is to develop secure order data from the commercial team, the following information is collected: customer data, product data, total consumer demand, delivery location, and delivery date. These data are retrieved from the funnel bucket utilising fundamental data analytics instruments. In this situation, S&OP teams typically hold discussions and news collecting to determine which organisations will fall into each funnel bucket. In addition, the S&OP teams create and preside over meetings for each action required for each bucket, such as irregular and large volume, where more communication with the customers and commercial teams is required.

For the second decision, which involves dividing the demand based on capacity, S&OP teams examine the consensus forecast data, which includes customer and product information, total demand for each customer, delivery location, and date of delivery. Using these data, S&OP teams divide demand by geography, such as the United States, Europe, Asia, and others. Then, factory managers provide S&OP teams with total capacity data for each facility in a specified region, including product data, maximum production capacity for each product, and factory location. The S&OP teams then match each region's supply and demand. However, if the plant in that region is unable to meet demand, the S&OP team must manually determine whether to place the order with other factories, delay production until the following month, or cancel the order. This is the second important choice the S&OP team had to make.

Analysis on S&OP framework of company

In a broader sense, these two decisions reflect essential S&OP objectives. The first is demand production, whereas the second is the integration of supply and demand. To comprehend what elements influence S&OP in reaching consensus and alignment between supply and demand, one must be familiar with the S&OP framework. It is evident from the context that the Pharmaceutical industry, client project data, and sales connection have a significant impact on the S&OP. These three factors determine how demand operates for this company. In the input, they emphasise the three essential areas of demand forecast, capacity, and factory inventory. This reflects both the supply and demand aspects of S&OP. This is also evident in the meetings and teamwork, with the two most significant meetings being with the commercial team for consensus prediction and the manufacturing manager for supplier inventory plan.

The technology utilised in the S&OP process generally provides minimal support for the process itself, such as demandtra for statistical forecasting and clicks, a data display tool. To analyse whether or not the S&OP process is successful, the performance of each factory and the accuracy of the prediction are used as metrics, which lead back to the previously described important decision-making in the S&OP process. The last components of an integrated production plan are procurement, production, and distribution. This is intriguing because in the preceding chapter, sales were also factored into the manufacturing plan.

Analysis on the forecast and challenges

S&OP was made to balance supply and demand, therefore prediction and through planning of both supply and demand is necessary. Company A being a pharmaceutical business-to-business company has expressed that their most important challenge is the accuracy of forecasting. As said previously, the company's largest customer are some of the big players in the pharmaceutical industry. Therefore, each of the customer projects to the larger company are highly important. The big customers orders large quantities, thereby making them the largest source of income in company A. Therefore, accurate prediction of how much the customers want, and how quickly the demand can change and plan accordingly to possible spikes in demand.

Based on predictions comes other factors like decision-making. Company A's S&OP manager explained that another element of challenge is decision-making as well. Making wrong decisions can jeopardise the big projects. The S&OP manager has to look the four buckets of the customers and their stability and volume. For instance, if the prediction of the demand is far off for the irregular and high volume customers, and the S&OP manager makes the decision to order the predicted demand, the outcome will become very costly. Through accurate prediction, the decision-making process also becomes a lot easier. In large organisations there are several hundreds of decisions that has to be made within the organisation. The head planner of a S&OP team can only make a handful of decisions, as there has to be done extensive analysis to gather what decisions that are important, crucial and is necessary to make. To make a decision, one have to look at different scenarios, weight the options and possibly look at historical or statistical data. This can be difficult if there are many decisions that has to be made in a short time period. A planner having to make 1000 decisions where only 20 are important, while the other 980 can be automated or assigned to lower management.

The demand planning is based on statistical and historical analysis, and the current state is quite adequate. However, when unpredictable external factors and internal factor occur the S&OP has to change and adapt. When Covid-19 hit, there were a lot of problems that arises in the S&OP. For instance, the demand for covid related medicines increased extremely and the medical supply companies around the world had been strapped for capacity. Another issue is the budget. The planners have two options, either to align to budget and find the discrepancies within the budget or redo the budget numbers. External factors are difficult to predict but can impact the S&OP in a high degree. Being able to foresee or having the possibility to make quick decisions can make a difference in the conventional S&OP.

Supplier visibility was also one of the concerns mentioned by the S&OP manager. A lot of the planning disruptions and capacity constrains are often due to the challenges suppliers are facing, which is external to the organization. Through integrating all functions within the company and factors external to the organization, it is possible to achieve a lot of data that will not only support demand planning, but also the planning aspect of S&OP. With that much data from several sources, the analysis will become much more advanced and accurate.

To achieve this might be ambitious, as there is a lot of data that has to be gathered and analysed. To gather the data, there needs to be a technology that could provide real time monitoring from the supplier side, which would enhance the planning and make it easier to combat challenges that come along the way. Integrating the supplier through real time monitoring of for example the supplier’s capacity or important information can improve the S&OP furthermore. Real time data can especially help in the demand planning as it can input changing external and internal factors, which can ultimately help the decision-making process. Automation of certain parts of decisions, like decisions that has to be done in customers with irregular stability and low volume can contribute to more efficiency and better use of resources. Therefore, there is a need for a technology to improve the S&OP.

5.8 Experts Introduction

As the company itself is not yet applying the DT within S&OP, there are two experts that will help in giving knowledge regarding both from S&OP and DT. Both experts are consultant within their respective expertise. The first expert is a S&OP digitalisation consultant that works in helping companies to digitalise their S&OP. The second expert work as DT specialist for the past 20 years. In this report, S&OP expert will give insight and the vision on how DT should be implemented in the S&OP, and the challenges that this implementation will face.

The DT expert on the other hand, will give information and knowledge regarding the DT itself and the experiences on DT implementation. This knowledge will help in understanding the practical possibilities in the DT application within S&OP.

5.9 Digital Twin Capabilities in S&OP – S&OP Expert Review

The S&OP experts shared his thoughts and suggestions on opportunities and challenges with digital twin in S&OP.

Opportunities through DT implementation in S&OP

Decision-making

The S&OP manager had some positive ideas regarding DT in S&OP. For instance, managers has to do a lot of decision making. A digital twin could gather data, manage it, clean it and make it available and visible, rather than doing it the manually. It was also suggested that a digital twin could organize the data and bring out the most important decisions. The S&OP planners could then look at the biggest exception and deal with them first. Another possibility is automating the smaller and unimportant decisions. Making decisions based on many decision points can be difficult, by using the digital twin to do simulations based on decisions being made would be much more efficient. The S&OP expert explains the benefits with an example as following:

"We have the digital twins, so I can start to run scenarios and anticipate the impacts of all of that and start to do trade offs and start to see what I want. The advantage of a digital twin is that I can do the pre S&OP trade offs, and show those to executives. If executives are asking for certain things, as long as it's feasible, I can quickly run things and start to add value. That's the advantage of a digital twin [...] its a powerful analytics to show executives. Everything is not detailed spreadsheets or it's not PowerPoints. I can have graphs and real time information in those meetings."

The idea is to run a decision and see how the reactions would be through simulation, for instance how the market would react. This would allow the S&OP planners to focus on the important decisions, and cut time, resources and money.

Visibility

In order to make decisions in the supplier part, supplier visibility is highly crucial. One of the challenges that the conventional S&OP is facing is disruptions and capacity constrains due to challenges suppliers are facing, which is external to the organization. Thus, it is necessary to have supplier integration and real time monitoring of the supplier's capacity, information etc. This is important data that could be fetched into the digital twin of the S&OP, to make important decisions.

Prediction

Predicting is another part of the digital twin. If a products' delivery is historically 10 days, the digital twin can make scenarios with 8 days lead time or 14 days lead time. Also, reacting to changes would be easier with a digital twin. External factors like weather, pandemics are hard to predict, but with a digital twin it can be easier to plan and make important decisions.

Integrating the components in S&OP

A virtual system like digital twin integrating all functions, from portfolio decisions to business process and then to the demand and supply planning would be beneficial. Having various sensors and datapoints from the different functions that will automatically be fed into the system, can help both in the aspect of decision making, but also in terms of forecasting. When all the functions are integrated in the system, making sensitivity analysis, it is possible to check the outcome implications for each function and decision that you make. Another benefit with integrating all the functions is, as the DT expert suggest:

“[...] If the digital twin itself has an analytic capability, that can then be showcased in the pre S&OP and executive S&OP. The data would flow based on the business process and the timing.”

Challenges through DT implementation in S&OP

Data

The S&OP expert also has his concerns regarding DT in S&OP especially in regard to data. The S&OP expert raised important questions like how the contextual data such as market price, inventory capacity, and logistic cost can be processed, filtered and incorporated into the DT. Each company have their own dataset and their own format. Companies leading in S&OP goes through and extensive process of the data, where they gather, clean, maintain it. Accordingly, the DT has to be able to do the same, which can be difficult.

People

One of the biggest challenges considering DT in S&OP was people according to the S&OP expert. Assuming that a DT was to be implemented in the S&OP, there has to be a whole team dedicated to the implementation that act as an agent of change within the company. Even though leadership in an organization is on board with the new technology, it will take time to convince rest of the organization. The expert manager commented on the issue and proposed that if the data and people are in place, the change management could perhaps have a successful project:

“[...] It’s less about the technology and more about the underlying surrounding processes [...]. Do you have the data, do you have the people, are they all bought in?”

However, if data and people are uncertain, the project could end up as a failure. People as in the planners have to be bought into the plan by change management. If the planners are not fully involved in the implementation process, the chances are that the planners will go back to their conventional way of doing the S&OP. The planners has to be involved in developing stage, get trained and tested properly in order to successfully complete the project.

Real-time data

The expert was also sceptical about the discussion regarding digital twin providing real-time monitoring and data. The DT expert explained his concern with real time process accordingly:

“[...] Generally, there’s a process to get it [data] from all the legacy systems, transform it into the format the digital twin needs, bring it to the digital twin, the digital twin uploads it, and then you can start to make decisions. You have to run solvers and everything, so that’s not really a real time process”

In conclusion, it would not really be real-time updates, as this “batch” with information takes time to be delivered. Another interpretation was that it would be difficult if the DT actually did provide real-time data. This is because the planners don’t want to continually make changes, every time something changes. For instance, if it is weekly plan, there has to be some kind of stability. Rather than changing the weekly plan every two hours, it would be more beneficial to change if some important information came up or some transactional data changes.

Confidentiality

Another concern is confidentiality. Security is a high priority as the information from the clients are confidential, and there has to be made precautions and not mix information with other projects. Usually companies have their confidential data in a cloud, and the key would be to extract the information in a secure way into the S&OP legacy and existing systems. Subsequently manage the data and provide it in a secure way. In regards to DT, one aspect would be that the information from the companies legacy systems and existing systems has to be managed and then provided to the digital twin, which could be complicated. Another aspect is if the DT gets hacked, and companies information leaks out or gets stolen.

5.10 S&OP Expert view on DT in S&OP – Reflection and Analysis

Interview with S&OP expert gives perspective on the opportunity and challenges with implementing a potential DT in S&OP through his extensive knowledge within S&OP and his common knowledge with digital twin and its capabilities.

The first opportunity that was represented was decision-making, where he suggests digital twin capabilities such as data gathering; gathering and processing data, automation; as in automating less important decisions, and simulations; simulate decisions and support choosing the best option. The second opportunity that was suggested was visibility in the supply side, through the DT capability real time monitoring. Other opportunities like prediction and integrating components inside the S&OP was also suggested. The S&OP expert proposed DT capabilities like real time monitoring through sensors and datapoints and provide real time data is one way to achieve these opportunities.

However, there are also challenges with implementing a potential DT in S&OP. The S&OP expert explained that data is the main challenge in this context, as gathering data from different datasets cannot be automatic inputs as they have different formats. Another challenge was to convince the people or planners working with S&OP to trust the DT and actually utilize it. Other challenging factors are the DT capability real-time data and security issues. The S&OP expert believes that real-time data is not achievable, and if it was possible it would be very difficult to work with changing data at all times. The security issues can also be a challenge if the DT gets hacked.

Altogether there seems to be both possibilities and challenges with a potential digital twin implementation in S&OP. Many of the challenges however are connected to the maturity of the DT itself, which is component that can be improved. On the other hand, people are a difficult and unpredictable challenge to work with, as there are many factors that plays a role in if it will succeed or not.

5.11 DT and its capabilities – DT expert Perspective

In order to extend the view on DT and to understand how DT can be implemented in S&OP, the topics in this interview with DT expert revolves around DT itself, its capabilities, and how to apply DT into new dimension, such as S&OP.

Definition of a DT

The DT expert defined DT as a digital representation of any system, and anything that virtually represent all the critical aspects of the system. DT is always defined as a two-way connection, for the purpose of always being in sync and provide change of state from the real system to the virtual system and vice versa. Another aspect of DT is that it has an analysable form where it can do “what if?” scenarios, and help discuss and analyse if something is done in the system. However, the expert explained that DT can be defined differently:

“ Different communities are using different kind of way of representing things. There are people who are using the historical data to say it’s a digital twin. [...] then, there are people who are specifying the behavioural aspect of the system, and says that this is the digital twin. [...] If you go to different people, they have different perceptions, when you say digital twin. So we need to be very precise and categorize”

The definition of the DT depends on how they are representing and utilizing the virtual model. If a system has a static environment and significant data, a thorough DT is generally unnecessary; one may just analyse and interpret the data. Similarly, if you have a dynamic environment and insufficient data to explain a complex system, you must implement DT to comprehend the dynamic behaviour of the system. It appears that the definition changes as the application purpose of the digital twin changes. Therefore, it is essential to specify why a DT is desired in the system.

The purpose of DT

Understanding the purpose of DT is essential for determining how it can benefit a system or entity. Compared to other technologies, DT is widely applied as an aid for decision-making or comprehension support. The DT specialist emphasizes that the objective of a DT is to comprehend or analyse a system. In essence, the DT seeks to comprehend why a system behaves in a particular manner. When there are unforeseen disturbances, such as global wars, operations can differ significantly. Therefore, in instances like that, it is necessary to create a DT of a system and have it evaluated the geopolitical impact. Another example where The DT expert illustrates how one of the many opportunities with DT, is in the following example:

“ [...] My system is not achieving my goal and I want to introduce certain things and you don’t know whether the change that you had in mind would actually help you to achieve your goal. In that case, typically what you do is introduce those changes in a real system and try to understand what will happen, but that requires building that system, implementation, and such kind of things which is very cost and effort intensive. So you may not be able to do it. [...] People generally try out things, then get the feedback from their reality and then try to refine it. [...] Instead of doing that, you can create a virtual representation and introduce the change in that representation and see what the consequence would be.”

In that example, it is also being explained that the purpose of using DT in a conventional system is because it is cheap and has a risk-free environment.

The function or capabilities of DTs varies according on the requirements of the system. DTs are utilized in various ways for various purposes. It can be used to simulate a decision, automate a process, generate or collect specific types of information, or gather experience data to aid in decision-making. Identifying the system’s improvement opportunities is essential to determining how DT can benefit the system or business. Lastly

Importance of Domain

Once DT’s purpose is established, the system or domain has to be identified. In order to determine what type of data models that should be used to develop the DT, it is necessary to have a comprehensive understanding of the system and all relevant data. The context is essential for effectively assessing the required data. For instance if the purpose is to examine the If the behaviour of a system, the system's domain will assist in evaluating the relevant facts, like using an expert in that domain. According to the DT expert, these are some of the factors to think of considering the domain:

"[...] What kind of concepts are there? How can we capture those concepts in a precise way? What are the micro behaviour, macro behaviour or emerging behaviour that are seen in this domain?"

The micro structure examines every component of a system. For instance, in S&OP, each system contains an abundance of dynamics, behaviours, and data. These data may not be monolithic, but rather scattered and inaccessible. To evaluate how the system as a whole is developing, one must combine all of its components. This will constitute the digital representation. Components can be departments, people or even machines. This is how the DT expert elaborates on how the components are essential:

"What is a department? Department is a combination of people and certain machines. And if people are behaving slightly differently, the productivity could be very different. So in that sense, you need to consider each of the people. Each person as a kind of element in the digital twin, so it's not a monolithic thing. You need to consider here depending on your objective. This is one extreme end of the use case where you have to focus on each element and sub element and all those things and then you construct a digital twin."

The macro perspective focuses on the big picture, hence the macro behaviours of the system are emphasised. In such situations, the model that does not consider all the minor components of a system, but rather the major ones. The DT specialist describes the macro perspective as follows:

"If you are willing to understand at macro level macro trained and their behaviour, you can create a monolithic model. If you want to go to a deeper level to understand those micro causality which is creating certain disturbance into macro behaviour. Then you have to create each of the systems as system model and put them together to understand what is happening."

Choosing appropriate model

Once the domain is defined, there are options for selecting the type of model to be used for that domain. There are characteristics used to determine the optimal model. Relevant data, the dynamics of the environment, and the size of the domain are three properties that must be examined. If relevant data are accessible, the data-centric approach is the most effective model. The data-centric model emphasizes statistical methods and time-series analysis. If there are insufficient data, the grained model is the best option. This model attempts to capture the entire system at a wide and aggregate level by employing system dynamics, model stock, or flow model as its basis. Then, the system environment will determine the grain size of this model. If the environment is static, a coarse-grained model is chosen since it is simpler and can be grown to a larger system. If the environment is very dynamic, such as the socioeconomic environment, a fine-grained model is employed. Notably, fine-grained models need intensive computation, hence they cannot be employed for large-scale modelling. Therefore, it is typical to blend fine and coarse grained models for simulating DT in order to reap the benefits of both types.

To summarize, in order to implement digital twin for a new system or sectors. There are three key component that needed to be decided. The first one is the problem itself. DT need to be created in order to solve a specific problem. The second thing is to determine the domain where the problem resides. This domain need to encompass all the aspect, properties, or behaviour that affect the problem. Then, the model should be conceived. The model type will differs depend on the data, environment, and the scale of the domain. After the DT is created, validation is needed to make sure that the model behaves exactly the same as the physical product.

5.12 Analysis on DT expert Perspective

In the interview with the DT expert on the extensive view of DT, there are a lot of important content that can help build the foundation for discussion in the topic of DT in S&OP. Firstly, the expert uses a broad definition of DT which are digital representation of any system. Then, he attach importance in a DT where it should represent all critical aspect and also in analysable form. How the system is virtually represented is similar with interview with S&OP experts where they use historical data as how they virtually present a system.

In the realm of industry 4.0, DT has its own important roles in assisting the industries. As stated by DT experts, the purpose of DT application over other type of Industry 4.0 is how it can aids in decision making and understand things. It is in line with the problem that being said by the S&OP experts in conventional S&OP.

Other perspective on why DT is being used also can be seen from how DT can improve both cost and risk within the conventional system. The first thing is costs, as it is a cheaper alternative to assess the possibilities of some option rather than exercise it on real system. Even though there is a cost in building DT, it is usually cheaper than trying the option in real life. The second thing, which is more important, is that it provides risk-free environment because it is not dealing with reality. As there are a lot of intangible assets that is hard to calculate such as customer satisfactory, trying new possibilities that impact this assets might be a big risk as it is hard to predict and often covered with other tangible assets such profit reduction. It is why the application of DT within S&OP for decision making whether to reduce the amount or to create better decision is very beneficial.

In the interview, there are capabilities of DT that is being mentioned such us simulation, data analytics, automation and visualisation aid. Those capabilities align with the result from the paper of DT in OSCM which are simulation, real-time data analysis and visualisation. Those key capabilities will help in solving conventional S&OP problem for example: simulation an data analytic can help in both decision making and assess external factor. Then, visualisation aid means it has capabilities in fixing supplier visibility issues. This means in a term of capabilities, DT has capability in fixing the conventional S&OP problem.

On the topics of creating DT within S&OP, the interview gave beneficial view on how DT model can be implemented later on within the context in S&OP. When thinking about S&OP, a way to improve it using DT is to build DT around S&OP process to help in data-decision making. As those process usually relates to aggregated data from many component, and it is more on behavioural rather than a physic law such as in manufacturing, DT needs to be created using coarse grained-trained model, where all the entire system is captured then aggregated. It is usually using supporting technology such as system dynamics and flow model. One paper from (yan, 2021) uses system dynamics in Digital twin for decision support tools for their management. The reason it uses system dynamics as there is a lot of dynamics within the management system. As S&OP also has a lot of dynamics within it, the application of this model is appropriate.

When creating the grained model, the appropriate decision is using a heterogeneous model where it contains smaller model using hierarchy structure, rather than using monolith model at the first place. It is because there are sub-element such as external supplier visibility that act as sub-elements within the DT. (discuss about a possibility of using 2 scenarios where it is monolith vs heterogenous).

Then, the heterogenous model need to use both course and fine-grain model to cater both of the needs of specific information such as external supplier and still scalable to a whole planning within S&OP such as DT of supply network as part of DT in S&OP network.

However, to understand which physical entity that this model might be applicable into, there is a need to synthesize this analysis with data gathered from S&OP interview

6 Discussion

6.1 Discussion on Research Question 1

DT concepts are universally recognized as a promising and novel research subject, as well as a strategic method for enhancing processes. NASA first introduced and described Digital Twin as "Digital Twin is an integrated multi-physics, multiscale simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history etc., to mirror the life of its corresponding flying twin". To date, however, the term DT has been used with a variety of definitions and objectives, often tailored to the needs of a specific context or application domain (Kritzinger, 2018). Numerous industries, including health, meteorology, manufacturing and process technology, education, cities, transportation, and the energy sector, have investigated how DT can improve or enhance their conventional methods. Understanding what DT means in a S&OP context is crucial, as it lays the groundwork for investigating research questions 2 and 3 and offers context. By comparing how DT is stated in various parts of OSCM, it is possible to infer how DT can be specified in S&OP. The DT expert explained that the purpose of creating a DT is highly important. The purpose of a DT will bring out the main domains that the DT has to focus on, which leads to how to the DT can optimize the S&OP and ultimately make it easier to leverage the DT in S&OP. There, this section will answer the RQ1:

What does a DT mean in the context of S&OP?

In order to address this question, it is necessary to first grasp the concept of DT. In chapter 2 the variation from digital simulation models and digital shadows to digital twins was discussed. Digital model was the first version of digital twin without any connection, while digital shadow was the second version with one-way connection, and digital twins bringing two-way connection. In chapter 4, the papers of DT in OSCM showed that the definitions in the context have some differences, but mostly similar in regards to defining digital twins. In manufacturing and mostly in production for instance, the DT is defined as a digital replica of a physical component that is always connected and synchronized with its digital component. In production the digital twin is mentioned as an advanced virtual factory, to emphasize that it is not necessarily a simulation of the twin, but rather an advanced technology. However, in the paper mentioning advanced virtual factory there is a smaller scope; as in the purpose is quite narrow and as a result, the DT has been defined differently. Contradictory to supply chain context where the DT is a digital representation or replica of a physical item, whether it be a product, process, or merely anything. In this context, the scope is much larger as the objective of the DT is not concise. Therefore, DTs having a larger scope has defined DT as a digital representation of any entity or system. This probably relates from the common understanding that a DT has a physical entity, connection between the two entities and a digital entity. Thereby, the definition of DT where the scope is broad stays somewhat the same in all the OSCM contexts. As explained in the theoretical background for S&OP tactical planning includes manufacturing planning, production planning, procurement planning and sales planning which is very similar to supply chain context. The S&OP is very broad and complex with both vertical and horizontal interconnections, therefore it can be assumed that S&OP's scope is similar to the majority of OSCM context, quite broad. Hence, it can be argued that the definition used for DT in

OSCM paper with broad scope, can also be used in the context of S&OP. Therefore the general definition of DT in S&OP context will be:

Digital Twin is a digital representation of any entity or system, bringing two-way connection between the physical entity and the digital entity.

Now that the DT is defined, the purpose of implementing DT in S&OP has to be defined. In chapter 4, the application and purpose in OSCM context is discussed, based on this it can be understood that the purpose of DT varies depending on the industry and application areas. For instance, in supply chain context the DT is utilized to gather all components into an integrated network, with the purpose of analysing the performance or behaviour of the system. While in planning and management context, utilizes DT to determine impacts of their decision-making. It is done through analysing all the steps in a planning process, and the DT would ultimately demonstrate a decision-option and show how it will impact the process. For instance, in S&OP tactical planning there is a need for decision-making in production planning, sales planning, procurement planning and distribution planning. An example of decision-making could be in procurement planning, where the DT would analyse through historic data and sensors, the most optimal hiring needs needed. In planning and management context this is important as they want the most optimal decisions. Thus, it is evident that the purpose is important as it sets the groundwork for the application areas and capabilities. This also corresponds with the DT experts thoughts on identification of the purpose being essential for where DT can be applied or utilized. Therefore, in the S&OP context both the case study manager and the S&OP expert suggested several improvement possibilities in their S&OP such as accuracy in forecasting, supplier visibility and external factors. However, it was expressed that the most evident problem in order to optimize the S&OP process was better decision-making. As S&OP integrates procurement, production, distribution and sales, the inter-connected decisions are many, therefore making the planning extremely complex, as explained in chapter 2. Decision-making in the S&OP process covers a large area as it is impacted by both external and internal factors. From the analysis of the case study there are two focus areas within decisions making; more accurate forecasting and demand distribution (This will be further elaborated in RQ 2). In order to do that, the DT expert emphasised that DT is utilized to analyse and understand the behaviour of a system. Therefore, to pursue the purpose, the behaviour of the system has to be analysed. Therefore, the purpose in this context is:

In this context, the DT's purpose is to enhance the decision-making by analysing the system it operates in.

Digital twin of what system or entity has to be defined as well. In production, physical object of the DT is a hardware. While in supply chain context, the DT is applied as an integrated network of components, like an entire supply network. While in the planning context the DT is of the whole system itself. The DT expert elaborates on two ways of a DT; micro structure and macro structure. The micro structure being every component of a system. From the case study and the S&OP theoretical background it can be established that the components of S&OP are many. In S&OP tactical planning a component could be procurement, as well as all the tasks involved in procurement, would be accounted for in the micro structure. If the S&OP process of the case study used the micro structure, there had to be a system each for data collection, demand planning, supply planning, and for executive meetings. Each of the components domain has to be inserted to system, like the DT expert suggested. With this structure, smaller decisions will also be accounted for and analysed. For instance, in the supply planning, decisions when the factory managers aggregate capacity data from small data components like sensors, in order to reach maximum production of the machine will be accounted for. While if the S&OP process used the macro structure, where there is a DT of the whole process, only the broader decisions would be assessed. Example of a broader decisions can be the general deciding on the secured demands, as seen in figure 9. Hence, for S&OP the most relevant DT would either be the micro structure or macro structure. Therefore the DT of the system are:

In the context of sales and operations planning, the digital twin may represent a network of smaller components like for example procurement planning or demand planning in the S&OP or the entire system as one.

The missing part is the DT capabilities that can be used in S&OP context. In chapter 4, four main capabilities were discovered; prediction & forecasting, real-time data gathering & communication, visibility & traceability and real-time data analysis. However, the most prominent capabilities used in the OSCM context were prediction & forecasting and real-time data gathering & communication. Prediction and forecasting are mostly used in manufacturing and supply chain contexts. One paper in supply chain particularly uses forecasting capabilities to develop a decision support system, which is similar to what is discussed in this section. Real-time data gathering is also relevant in this context, as it is used in OSCM to achieve real-time data in order to make analysis or to support initial decisions. The S&OP expert suggest somewhat similar ideas such as real-time data gathering, where the data could also be gathered, managed, cleaned and visible rather than doing it manually. Along those lines, the S&OP expert also included simulation analysis as a way to run decisions and see the impacts of the decisions through simulation. These are relevant capabilities to assess the decision-problems in the demand and supply context, which will be further elaborated in the RQ2. However, the capabilities in this context are:

In this context the DT is utilized through real-time data gathering and forecasting and simulation-analysis.

Considering all these factors, the authors of this paper has come to an understanding of digital twin in S&OP context. This is done through the comparison of how other papers within similar contexts have defined digital twin, theoretical foundation of digital twins and the case study manager and experts. The meaning of DT in S&OP context is:

Digital Twin is a digital representation of any entity or system, bringing two-way connection between the physical entity and the digital entity. In the context of sales and operations planning, the digital twin may represent a network of smaller components for example procurement planning or demand planning in the S&OP, or the entire system as one. In this context, the DT's purpose is to enhance the decision-making by analysing the system it operates in. This is achieved through the DT capabilities real-time data gathering and forecasting and simulation-analysis.

6.2 Discussion on Research Question 2

Using case company as an example, conventional S&OP faces two obstacles. The first is the accuracy of the prediction. S&OP requires S&OP teams to produce accurate predictions to reduce shelf-bound product waste. The second is the distribution of demand among suppliers. This procedure required manual effort, particularly when the demand cannot be met in the typical manner, since S&OP teams must calculate the price when procuring through alternative channels or have discussions with the customer if the price is unsuitable and the order must be postponed or cancelled. To thoroughly study all the properties of that problem, both of its characteristics must be investigated.

Deviation in forecast accuracy

In the case of the accuracy of the forecast, it is necessary to comprehend the type of data that was predicted, how the prediction is constructed, and what components are involved. Predicting the quantity of demand from clients is the focus of demand forecasting. Based on the case study regarding the data used, this prediction is based on two types of data: secure customer order data and statistical forecast data derived from historical data. Both datasets contain the quantity of consumer demand. However, the data from secured orders are significantly more accurate than statistical statistics. The data from secured orders comes directly from the customer, hence the data's integrity is quite high. On the other hand, the data from statistical forecasts are derived from historical sales data, which can be utilised as a starting point for demand data but is less accurate than secured order data. But as it is easier to use this statistical forecast by using application such as demandtra, statistical data is used as the starting data for consensus forecast data. The creation of consensus data begins with the use of statistical data to fill in the blanks, followed by the use of secured order data to replace those values. For customers who do not have the data provided in secured order data, statistical forecast data is used instead. In here, S&OP team need to check the secured order data and decide whether it is in line with statistical forecast. Also, S&OP team need to decide whether they want to accept the order or not based on their knowledge on the environment.

Both the decision making that being done here and the nature of the demand data is the reasons for the difference in prediction accuracy, as not all customers provide their demand information in a timely manner, and when considering the nature of statistical forecasting, it only uses minimal data such as previous demand, interest rates, and other mathematical data to extrapolate future demand. Even though the information from a customer-secured order is more dependable, it is not immune to change. As previously described in the case study, demand is vulnerable to fluctuation because the majority of customers are large corporations. This is not a problem in industries where demand is consistent; but, in the pharmaceutical sector, demand fluctuates frequently for a variety of reasons. Clinical trials, global demand for a product, medical recommendations, formula retention, and the emergence or disappearance of an illness are some of the reasons.

These factors led to three primary causes of demand prediction inaccuracy:

- Variations in customer demand
- absence of customer demand data
- Statistical forecasts lacking in variability

Variations in customer demands are highly related to the context of S&OP that are already described in S&OP framework, which are customer project data and the nature of the pharmaceutical industry itself. If the nature of these projects is highly dynamic, such as when large corporations place a large number of orders to provide a large number of their projects that are still in clinical trials, then the rate of demand fluctuation will be exceptionally high. However, despite the fact that the order will be utilised for products that are already on the market, the nature and functions of products must also be considered in this industry. For instance, if the order is for covid vaccine ingredients, it is necessary to forecast and comprehend how demand would alter, given that practically everyone is currently vaccinated. Here, the ability to foresee possible outcomes has become crucial. Inaccessibility of client data also contributes to the lack of data for prediction. This problem is especially prevalent among customers who do not place large orders. However, as there are a substantial number of these consumers, it affects the accuracy of the demand forecast. A plan to engage with these tiny businesses may be enticing, but its implementation would be prohibitively expensive and labour-intensive. Therefore, a tool that can identify or assist in predicting this type of customer is required. Lastly, the result of the statistical data is inadequate because it only considers prior demand as a factor influencing current demand. In a fairly stable environment where all elements affecting demand are similar, this is sufficient; however, in a more dynamic context, it is not sufficient because ultimately, the price is also subject to a number of variables. To solve these issues currently, S&OP team talks to people and manually plan and adjust the statistical data based on the research

Decision in demand distribution

The second issue, which relates to decisions in demand distribution, is wholly centred on a separate component of S&OP. In this case some of the data that already discussed in S&OP framework such factory data will be utmost importance. Rather than focusing on demand, the primary objective is to supply that demand within the cost accepted. This cost is affected by strategic plan. In order to determine which factories will fulfil the demand, the S&OP team is grouping the demand based on geographical location, and then assigning the demand to the factories in each of these locations.

Thus, all European demand will be handled by the factory in Switzerland, while all Asian demand will be handled by the factory in Singapore. This ensures that distribution expenses are kept to a minimum. However, not all factories are able to meet the demand in their regions. If the nearby plant is unable to meet demand, S&OP teams must determine whether other neighbouring factories can meet demand, as well as compute the increase in production price and delivery date.

If one of the values is very high, the S&OP team will discuss with the client whether they will continue to provide the demand despite a price rise, delay the demand, or even cancel it. All of this is performed manually under the supervision of the S&OP team.

This division of demand is labour intensive and requires the S&OP teams to make numerous minor decisions. There are two essential steps in this decision-making process. The S&OP team must initially group and divide the demand. The S&OP team must also resolve the irregularities. The first essential activity is a sort of logical decision-making in which technology could be used if it adheres to a specified set of rules for grouping and dividing demand. However, the second activity is a meeting with clients, which is an organic activity. However, technology that can help determine the best solutions would be extremely useful in this circumstance.

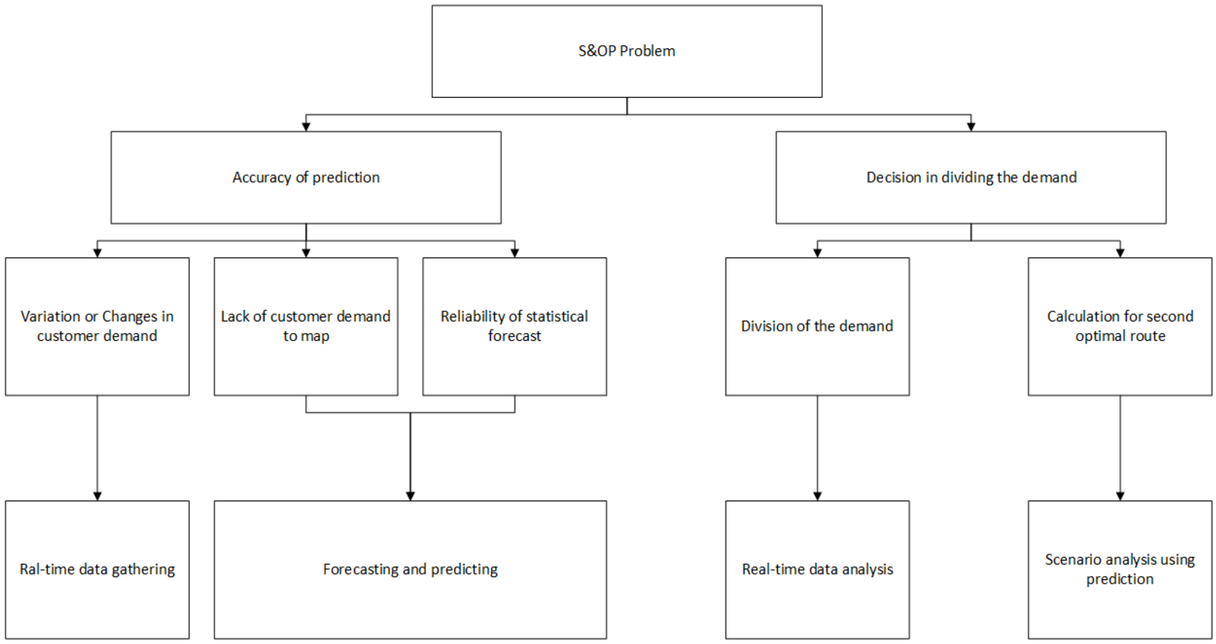

Figure 13 S&OP problem and DT capabilities

Figure 13 shows the capabilities of DT that can help those problems. Real-time data collecting to boost the reaction of demand from the huge clients. To boost the response to the changes of demand from big clients, real time data collection is used so the companies will be alerted about the changes as soon as possible.

Real-time data collecting / Gathering to improve the response of demand from the huge clients. To boost the response to the changes of demand from big clients, real time data collection is used so the companies will be alerted about the changes as soon as possible. This will lead to a lead time where the corporation has more flexibility in cutting off or adding more order based on those changes. Other capabilities that useful is prediction and forecast, which can help in forecasting the changes in the demand of the huge clients.

However, this can be proven challenging as the idea of building digital twin of the clients is highly complex. Even though it is complex to create a DT of big customers, it is still doable in the small customer with stable environment, hence prediction and forecasting also other capabilities that can be applied here. This capability can be used to improve on the missing data from the consumers. by building a simple digital twin for something that is stable, digital twin can help in making the prediction of the data that will be needed for statistical forecast. Or an even better way, the analytical program can be changed from a statistical forecast program to be more using a cluster of simple DT of the customers. This cluster will combine chosen data that can be observed by the company and the previous demand to create a data for today’s demand. Even though it might be not resulted in the most accurate data, but it should be more accurate as it also considers other factors that shapes the demand. Prediction and forecasting by using DT of a customer that takes the input based on historical data and product trend

Real-time data analysis can be utilised to make the division process easier. By having a real-time data analysis, DT can improve the process of clumping together neighbouring demand and choosing the nearby factory. Also, DT can help analyse which demand that cannot be provided by the nearest firm because of capacity limit. Analyse the route, cost, and distribution line to simplify the decision

Lastly, **scenario analysis by combining both prediction and data analysis** can help to propose the best option to the clients when the normal supply division doesn't work. DT will propose the second best supply plan for the clients. From this options, clients can choose whether to use that optimal solution, delay the demand, or cancel the demand. Predicting and forecasting of each line that has been analysed to show the customer the best option

6.3 Discussion on research question 3

The previous section described the two problems and the corresponding capabilities that can aid in their resolution. Those capabilities are needed to solve the problem within the conventional S&OP. To apply those capabilities into the S&OP, papers with similar capabilities can be chosen as the inspiration to solve the problem presented in the S&OP. By identifying the problem from the S&OP case, and then match the problem with the similar problem from the literature that can be used to solve that problem. By using framework from the referenced papers, solution to those problem can be achieved. This is because there are no exact digital twin solutions that can be used for all problem in S&OP context. Then, those solution is supplemented by the views from both DT and S&OP experts.

6.3.1 Demand optimisation

To tackle the first challenge, DT can be implemented in two different areas. The first areas will provide DT capabilities for real-time data gathering in order to be able to notice the changes in the demand, so the consensus forecast is using the latest demand. This latest demand should be able to already taken into consideration all the factors such as economic consideration, inflation growth, and other factors that impact this demand as S&OP managers needs more time to calculate that therefore the consensus forecast date might be delayed.

A DT models that can accomplish this goal is a virtual product that track product properties throughout all of the product lifecycle. All modifications throughout the product's lifecycle will be mirrored by the virtual product or the twin itself in this type of model. This will create visibility and real-time data gathering for the products, allowing the organisation to respond swiftly to demand-related adjustments. Tao (2019) has done this by developing a DT for the bicycle, and any changes in demand or customer application habits will impact the design and manufacture of the product throughout its lifecycle. The idea of this DT of the products can be implemented, as the changes from the big clients cannot be seen by only asking for the demand itself from those companies

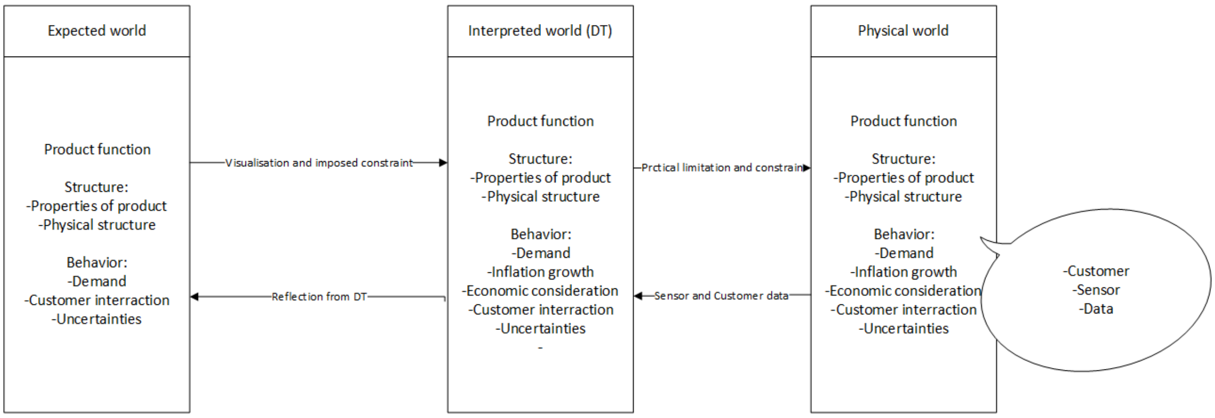

Figure 14 DT of Product (Inspired by Tao (2019))

Figure 14 shows how a product's DT can be developed and how the changes in demand can be seen. Expected world, interpreted world, and physical world are the three dimensions that are used in this model. To describe the product properties that want to be developed, function, structure, and behaviour are three key components. The product that developed by this company are half-finished product with a specific function and a sole patent holder of those product. When creating that product, a specific expected function, structure, and behaviour are identified. Then a digital model is constructed with more enforced constraints and additional data, such as inflation growth, economic considerations, and all other product behaviour data. Finally, those products are developed and released onto the market. Sensors and customers in this sector provide feedback on what transpired and transfer that data to an interpreted world. Adjustments are made based on that data in the interpreted world, and those data are represented in the expected world, where the corporation decides what adjustments to make based on that data.

One example of this model application is when developing a substance that is one of the ingredients for pfizer vaccine. In current S&OP process, Pfizer will send a demand request, and then the S&OP manager will discuss with pfizer representative and determine how much order that will be placed based on the discussion and the S&OP managers view on the current market, as the decision also needs to consider the market changes. S&OP managers in this case is using their own knowledge in for deciding safe buffer stock for this demand. However, even though the demand and buffer stock has been calculated, Pfizer may make some changes in demand or specification based on the market condition, which led to deviation in demand projection. For S&OP managers, latest data is needed so those changes can be catered by the production team, hence a model that can give real-time data gathering is needed for S&OP managers to be able to make best decision for the demand based on the latest data that they can get.

With this model, case company create a digital model of the substance, that contains its function, chemical structure, and the behaviour especially demand behaviour related to other factors such as how the demand changes based on interest rates, customers location, etc. Then, after the substance is sent to the customers such as pfizer, S&OP digital model can collect real-time feedback from customer using digital platform such as mail, or website and also gather data from sensors that tracks how much product that used the substance in the market. By gathering all of those data real-time, the digital model can do analysis from all those data and gives expected demand for the product based on that data. Therefore, even though customers need to process those changes before giving it to the case company, case company already has the similar data that can be used by S&OP managers to decide the amount of demand projection.

The second area where DT can be used will provide forecasting and analysis to predict the demand from small consumers who did not submit requests. It is accomplished by generating a DT of each client and performing predictive optimization of demand using both numerical data, such as historical demand, inflation growth, and economic considerations, and behavioural data, such as the present relationship between the company and the consumer. The idea of using DT for prediction has been used by Wang (2020), where the paper creates a DT model diagram to optimise the demand by analysing elements that changes the demands. In that paper, the model is closely tied to the case study which are optimising demand in remanufacturing factories. Extracting from the paper and model presented in Wang (2020), the idea of DT is by acquire all the data that change the demand. Then, those data are processed and used to create a model of the customer demand (market), product, and manufacturing process. Then, simulation and data analysis can be done by the model to show expected demand based on the data. Based on the expected demand from the DT of customer demand (market), DT of product and process are changing their properties and those properties became an input that drive the manufacturing process. Synthesizing from this idea and case study resulted in Figure 14.

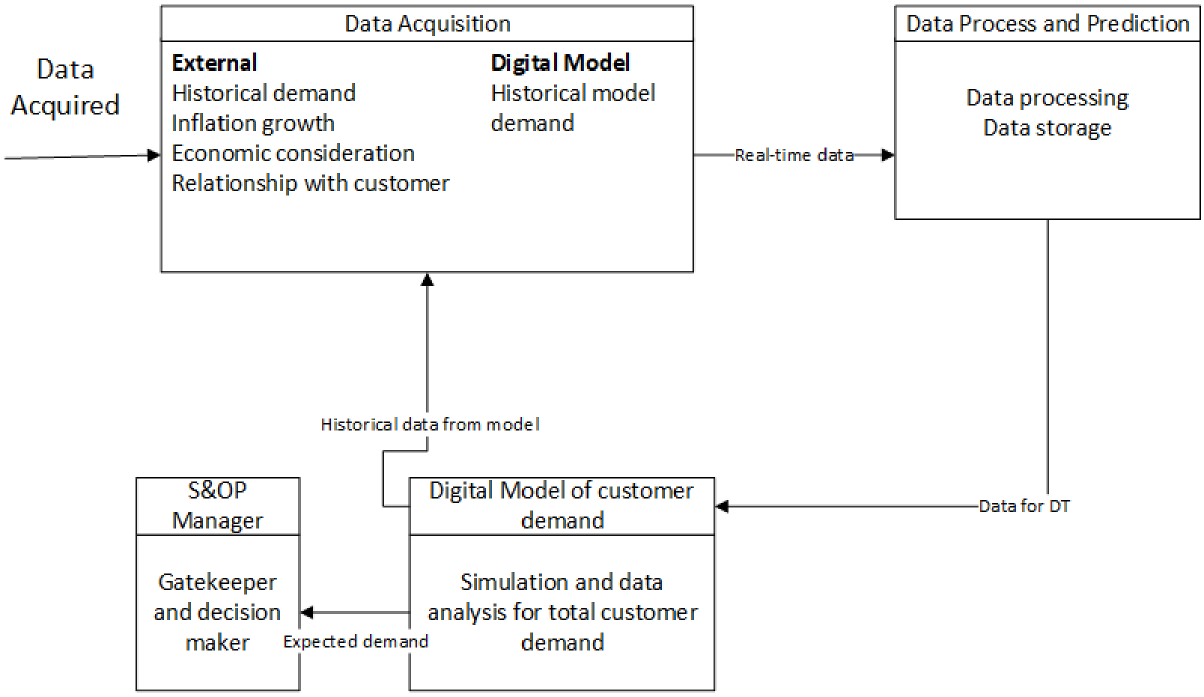

Figure 15 Digital Shadow of customer demand

Figure 15 illustrates how a digital shadow (DS) of customer demand assist S&OP managers in forecasting demand for small businesses. This model can contain other types of data, not simply mathematical data, which makes it potentially better than statistical data. Data is gathered from the environment in this figure, such as historical demand, inflation growth, economic considerations, and customer relationships. Also, historical data from digital shadow is part of this data acquisition. After then, the data was processed and stored. The data will then be entered into a digital model of customer demand, where simulation and data analysis will be performed in order to determine projected demand based on all of the information. S&OP managers will review the predicted demand and decide whether it will be used or manually overridden if it is not appropriate.

The historical data from this model will then be incorporated in the subsequent simulation as part of the data. The model has no effect on the physical system of that, as seen in the illustration. As a result, it is a digital shadow of the customer's demands rather than a digital twin. This is main difference between this model and the idea of DT by Wang (2020), where rather than DT of market, product, and process, this model only focuses on the customer demand.

6.3.2 Supply optimisation

The second issue, which relates to demand division decisions, is wholly centred on a separate component of S&OP. This section is focusing on how DT can help in optimising the supply. In order to determine which factories will fulfil the demand, the S&OP team is grouping the demand based on geographical location, and then assigning the demand to the factories in each of these locations. In the S&OP case study, the S&OP manager explained that their first priority in regards to supply, is that the distribution centre is close to the customer. The lead-time of distribution was his first priority. It may be conceivable that it is straight forward when choosing the closest factory to the costumer, in order to comply with the lead-time. However, the problem arises when there are several customers and limitations in production in the nearest factory. The S&OP managers has to then map which of the customers are closer or closest to other factories. Then, if the price or delivery times for that demand cannot be fulfilled, S&OP team will have discussion on how to approach this demand. If the customers still want those demand to be fulfilled for the same month, discussion will revolves around choosing which factory that they can choose and whether the customer prefer increased costs or late delivery in that month. However, the customers can also choose to be supplied in the next month or even cancel the order. This is how the current supply plan decision are being made by the S&OP manager. This can be a waste of resources, as it is time-consuming and has to employ a lot of man-power. Instead, a digital twin could provide real-time data analysis for automatic supply plan decision and scenario analysis to propose the closest factories for the independent customer.

One digital twin model that can help in solving this problem is a DT model of supply network such as the one that used by Burgos (2021). Burgos (2021) proposed a model that would represent the whole supply network state, and then use that to simulate and optimise the best possible network route for supplier and transportation. The model uses real-time data gathering and simulation in order to customize the best route for the supply. This DT model can be a possible solution to detect the most optimal factory for the different geographical customers in order to stay within the lead-time. Similarly, there are other capabilities that can be gained from using DT of supply network as a model, which are scenario analysis by predicting and forecasting the supply route to find the best option that can be discussed with the customers. By using this DT of supply network chain, each alternative factory can be checked and the price and delivery date for each route can be obtained. By using scenario analysis to predict how supply network plan would be if that demand is fulfilled by each of the alternative scenario, the optimal supply network and factory that will take that demand can be achieved, However, ff the cost is too high to procure this demand, S&OP team can have a discussion with the customer by showing these results and let the customer decide whether to keep the demand albeit increased costs, delay the demand, or even cancel the demand.

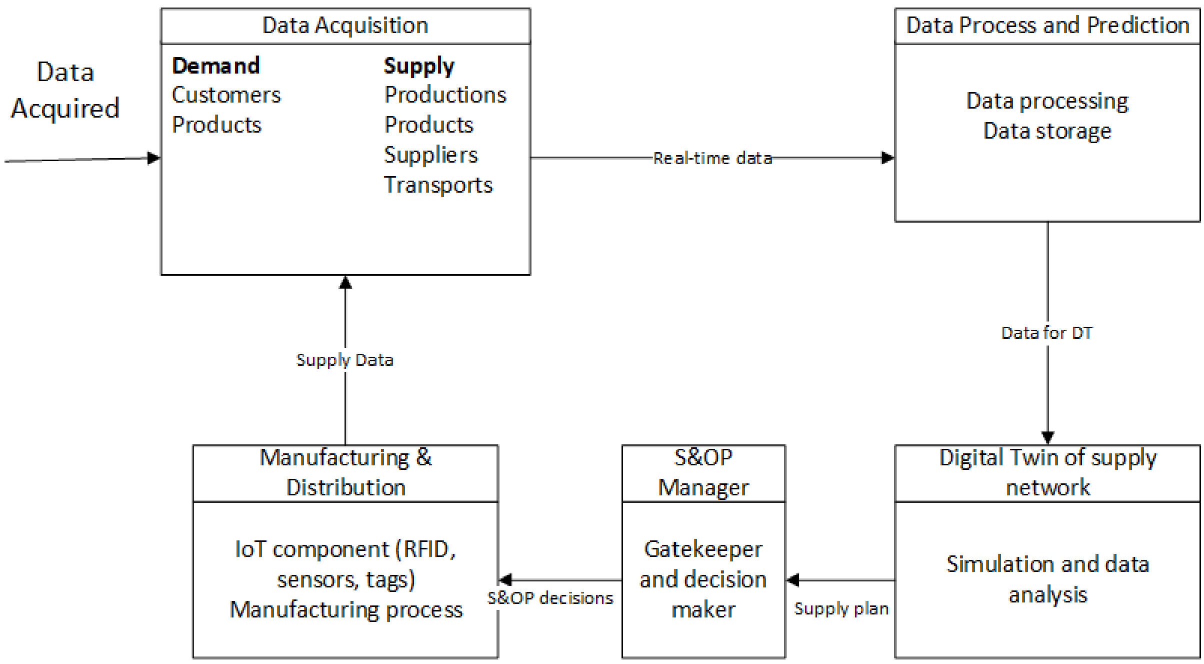

Figure 16 Digital Twin of Supply Network

The idea of how the digital twin of the supply network would support decision-making in supply distribution challenges is presented in figure

Figure 16. This figure is synthesized from case data and Wang (2020). There are 5 steps that used for DT to help S&OP manager in creating a plan and make a decision.

Data acquisition includes demand data and supply data. The demand is provided through forecasting data, which brings in the customer demand and the product demand. While the supply data is provided through sensors from the manufacturing side. The data in the supply side includes information from production, distribution centres and the products. It can be seen from the figure that the DT itself does not provide data in data acquisition, however, the output of DT will be read by the S&OP managers and the manufacturing process will be done based on the decision that being made by S&OP managers from DT output data. In a way, this is how the supply network twin contribute into the supply data. The data acquisition is gathering all this data and sending it in real-time to the *data process and prediction.* Here, the real-time data will be processed using methods that used in big data analytics and then saved in data storage. The purpose of this process is to gather and clean the data to achieve the same format, in order to insert it to the *DT of the supply network*. When the data is brought into the DT, the DT will utilize its simulation and data analysis capabilities to provide a optimal supply plans. The supply plans will be presented to the *S&OP manager* which will act as a gatekeeper, and make the decision of whether the plan is up to standard, has the changes or if it is approved or not. The reviewed supply plan is then given to the manufacturer and the manufacturing starts. Then, from the manufacturing factory, necessary supply data is updated and sent. This new ways of creating supply plan is created based on synthesizing literature with the data that are available and used in the S&OP of the study case.

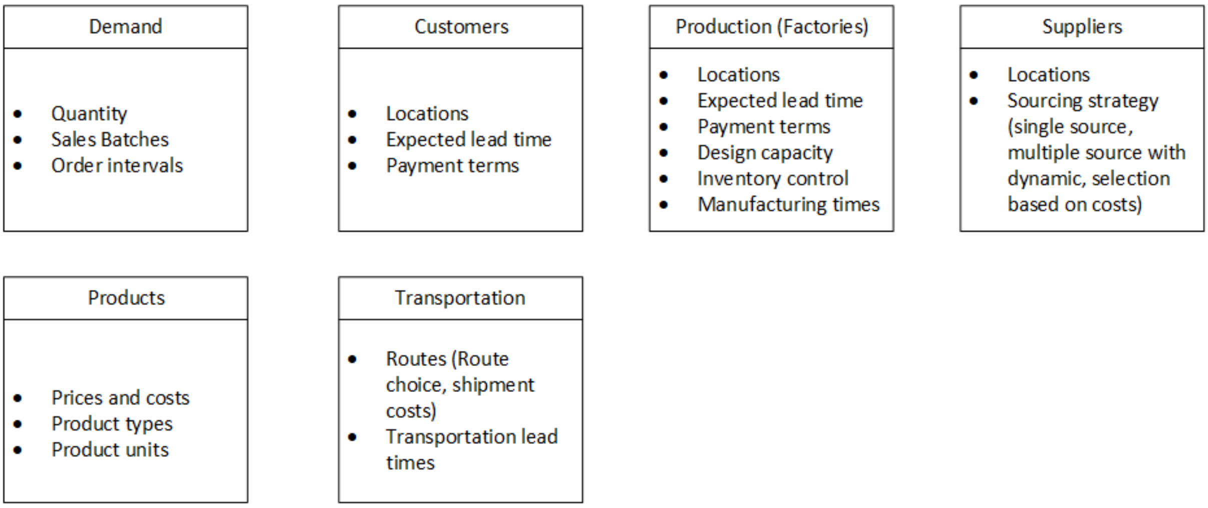

Figure 17 Data for DT Supply Network

Further on in the expanding the data acquisition for better DT of supply network,

Figure 17 shows all the data that can be potentially gathered to create DT of supply network. Even though currently the case study does not use and have any means to gather some of those data, those data can help in creating better supply network twin such as the one that used by Burgos (2020). How those data can help in creating better supply network twin model can be explained below.

If the customer is a Covid-19 supplier the demand would include the consensus forecast, which consists of factors like quantity and order intervals. While the customers information is also gathered which can be the location, for instance Norway, and the expected lead time and payment terms are also incorporated. The product information itself is gathered both in the demand and supply side, which can include the cost, how much raw material is needed, how many units and so on. In the supply side of the data gathering the production location, the expected lead time and payments terms are included. Then the same information has to be gathered from distributions centres, and their processing time and inventory control also has to be accounted for. From the suppliers of the raw material needed for the covid-19 for instance, the location and the sourcing strategy has to be included. Lastly, the transportation is also very important as it shows the routes, the shipment costs and the transportation lead time.

After gathering all the data, the data will be processed and made available to be applied to the DT of the supply network and the outcome will be a supply plan. The supply plan will provide information of how the S&OP could optimize the plan or show the best options for delivering the products. For instance, if the covid-19 vaccines were originally made in the factory in Netherlands with the order quantity of 1000 products, but two of their production entities broke, then the DT will generate an optimal plan to deliver to the customer within lead-time. However, the cost might increase, hence the S&OP manager has to manually talk with the customer on how they want to find an appropriate solution. If the lead-time is the most important, or if the costs are the most crucial. Then the S&OP make the according changes and send it to the manufacturing.

To conclude both demand and supply optimization and how those DS and DT can help in improving the conventional S&OP,

Figure 18 show how DS and DT can be leveraged in the conventional S&OP. From

Figure 18, each of the steps in the S&OP process can be improved by leveraging digital model and twin into each of those process. By implementing those digital model and digital twin, it can create benefit to S&OP managers and S&OP teams in term of their planning.

S&OP Process steps-by-steps	Data gathering	Demand Planning	Supply Planning	S&OP alignment Meeting
How DIgital model and twin used in S&OP	DS of customer demand are used to predict the amount of demand from the customers that does not submit order at given time.	DT of product used to detect changes in the demand so the demand that used will be the latest demand	Supply network twin will provide most optimal supply plan for each of the demand. Supply network twin also able to do scenario analysis to find the second or third best option if the most optimal solution cannot be achieved.	Digital model of customer demand and DT of product Used to visualise the demand and analyse the causes of deviation. Supply network twin Used to visualise current supply network to plan for expansion if necessary
Digital model and twin used	DS of customer demand	DT of product	DT of supply network	DS of customer demand, DT of product and DT of Supply network
Main capabilities	Prediction and forecasting	Real-time data gathering	Prediction and Data analysis	Supporting tools in visualisation
DT benefit in planning and decision making in S&OP	S&OP manager gain more accurate prediction than normal statistical data as it can cater behavioural data	Reduce the risk of deviation in consensus forecast as S&OP managers are creating the consensus forecast using the latest demand	Reduce planning burden in supply planning as DT analyse and recommend most optimal supply plan. Also, S&OP managers already have scenario that can be discussed wih clients if the demand cannot be met in normal plan.	Help visualisation of the S&OP data to assist for planning in longer time horizon

Figure 18 Leveraging DT / DS in S&OP

Analysing Figure 18, each DT and DM are used separately in each of the S&OP process steps. This happen because of each steps has different problem or challenge that faced by S&OP managers in term of planning and decision making in S&OP. This is in line with the result from discussion with DT expert, that conclude DT is conceived in order to solve specific problem. This is also why digital model is used rather than digital twin in data gathering step. It is because the main problem is lack of demand data from the customers. Here, case study wants to create more accurate prediction for the small customers demand that are usually not available / not submitted by the customers itself in early phase or production. This means the two ways connection is not needed, as DT cannot changes the demand from the customer. Hence, digital shadow where it takes environment and historical data is created as one-way connection to the model. In DT of product that used in demand planning, the output of DT used to change the demand in forecast so when S&OP managers and other function create a consensus forecast, the demand that used are the latest demand. This shows two ways connection between DT of product and the product itself especially in the demand. It is also the same as DT of supply network, where the result of DT will be used to plan the supply network, and the data from supply network will be used in DT later on as part of input data. This also shows two-way connection between DT of supply network and the supply network itself. Those are how DT should be leveraged in S&OP context. Further on, there are some recommendation of how DT models should be created and the challenges in DT implementation

6.3.3 DT models

There are some recommendation for creating the DT that listed. The first two models are a model that uses market data as the input. This may lead into more challenge such as how to gather those external data and the means to gather it. The last model however, it is DT of supply network chain where all the data can be gathered in-house. After determining this domain, the model's characteristics can be discussed.

Due to the limited amount of relevant data that can be collected and the fact that more than simple numbers are being examined, the model should be coarse model. This is due to the fact that this model incorporates behavioural aspects of the physical chain. The grain size model should then be discussed. Based on the conversation with DT experts, the grain size will depend on the scale and level of complexity of the DT. The scale of the supply network chain is global; nevertheless, although the data is large, it consists primarily of aggregated data and not specific data. The detailed data is only required if the demand cannot be met by the nearby factory and must be completed by another factory.

In this circumstance, it is necessary to have complete knowledge of the cost, delivery date, and delivery technique. It indicates that the DT model can combine coarse grain and fine grain models. In conclusion, the model proposed for application in this S&OP example is a grained trained model with a grain size combination.

6.3.4 Challenges in implementation

The potential solutions for the challenges presented in the papers, must consider the aspect of challenges with DT implementation. The S&OP expert emphasized that data collection and people would be the primary obstacles to deploying DT. In data collection, the ability to gather, sort, and synthesizing all the data is a challenge in regards to the sheer amount of data for the DT itself. For the people, the willingness to try and stick into the new technology is also the challenges. To create a network of the suppliers; factories and customers, there needs to implement certain information technology product within the factory to gather some data such as actual capacity. Those implementations of new IT may provide challenges especially for the peoples within the factory to embrace those new IT within their workflow. Another aspect is the people in the S&OP department itself have to be convinced to utilise the digital twin to identify the best cost- and time-efficient opportunities for their customers.

7 Conclusion

This thesis examined what DT is in the context of S&OP and how it can be implemented in S&OP. In the theoretical foundation, the relationship between DT and S&OP is established, since DT is one of the technologies capable of leveraging conventional S&OP, despite the fact that there is no literature about DT in S&OP and the closest literature comes from OSCM, which is a more broad S&OP dimension.

In the study of relevant literature, the definition of DT and its primary capabilities are examined. The definition of S&OP and the four primary capabilities of DT that will be utilised in S&OP are proposed based on the literature.

The application of these skills to S&OP will be discussed using a single pharmaceutical business case study. The case study deconstructs S&OP from its process into the decision making and how the data is processed, as it is found that decision making is a major issue in S&OP.

The discussion of this subject led to the identification of two crucial decision-making issues: deviation in determining demand due to inaccurate demand forecasts, and the selection of factories to meet demand. Inaccurate demand forecast that used by S&OP managers to decide demand projection will led into excess product in that month. In the selection of the factories for demand, S&OP managers need to group the demand, and decide which demand that will be taken by each of the factory. This labour process can be solved by using logic and mathematical modelling. However, as the S&OP managers need to discuss with the customers if there are demands that cannot be fulfilled in the given time and costs. Here S&OP managers need to propose options to the customers, which leads to another labour work for S&OP managers. After understanding those two problems, in order to comprehend how DT should be utilised to address these two issues, the S&OP application of DT is discussed with S&OP experts. In order to gain a comprehensive understanding of DT, it is necessary to obtain expert opinion. The DT application can be conceived using all of this facts.

Using the case study as an example, the proposed definition of DT is expanded to determine whether it is suitable. This thesis then provides the S&OP definition of DT. The issue is then examined and dissected so that its essence is made evident. By introducing the proposed capabilities of DT, each of these critical issues can be handled. There, all comprehension and reasoning are discussed.

This thesis concludes by proposing how DT can be applied into S&OP depending on both the problem and capability. Using problems as the primary objective and DT capabilities as the determinant to solve that problem, the domain of DT can be found after analysing all the elements that affects those problems. Lastly, the model and the difficulties associated with DT implementation are described.

The conclusion of this thesis is that the definition of DT is that Digital Twin is a digital representation of any entity or system, providing two-way connection. In the context of sales and operations planning, the digital twin may represent a network of smaller components in the S&OP or the entire system as one to support demand projection decision and supply planning of S&OP. Digital twins can serve multiple purposes, but in this context it is utilized through real-time data gathering and forecasting and simulation-analysis to enhance the decision making, by analysing the behaviour of a system. One example of the system is supply network for the production.

There are three application areas for design thinking. DT of client product, DT of client demand, and DT of the supply network. The obstacles in implementing DT focus around the volume of data that is processed and the individuals who will apply it, regardless of their resistance.

This thesis provides a qualitative approach to the implementation of DT in S&OP. It is strongly recommended that the finding be validated by quantitative analysis. As this implementation uses a single company as its starting point, additional investigations with other companies are required to substantiate the claims being made in this thesis. The finding indicates the application areas for DT.

Further research can be conducted on the deployment of DT in these specific domains, as it is necessary to determine an appropriate domain boundary, where all the elements that impacted the problem is being identified and verified by the domain experts. Next thing is to check whether the digital twin can handle the problem presented in this thesis.

This thesis has examined the possibilities of digital twin implementation in S&OP. However, the deployment of DT technology itself necessitates more sophisticated expertise from both DT experts and S&OP experts in order to identify both boundary conditions and appropriate technology and modelling in order to create such models. Additional research should investigate how to implement one of the DT recommendations using a real-world case study.

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