Supply Chain Planning in the Food Industry: Empirical Studies on the Adoption of Advanced Planning Systems

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Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Abstract

Supply chain management in the food industry is challenging due to multiple factors such as the limited shelf life of food products. Supply chain planning (SCP) is required to balance the demand with the supply of products. Advanced planning systems (APS) constitute the technological means for sophisticated methods of SCP. APS can contribute to improved decision-making and enhanced efficiency along food supply chains. However, studies reveal limited implementation of APS in practice.

This thesis investigates the level of APS implementation in the food industry and factors affecting the adoption of APS by means of mixed methods research comprising a survey among food producers and expert interviews. The study confirms the limited use of specialised software for SCP. Many food companies perform SCP tasks by basic functions of enterprise resource planning (ERP) systems. Lack of human resources and costs associated with implementation projects inhibit companies to adopt APS. Supply chain complexity induces food companies to adopt APS. Besides enhanced planning accuracy, the usability of APS is regarded as particularly important by companies. Based on the findings an adapted technology acceptance model (TAM) for the context of APS is established. In addition, the research provides practical advice how implementation projects can be facilitated. Companies need to ensure the availability of skilled employees, highlight process requirements, and prioritise data quality. Management support for the software implementation should be maintained throughout the project. Furthermore, companies should strategically reflect on SCP practices together with company goals to ensure proper software selection.

The analysis of quantitative and qualitative data reveals a comprehensive view on APS implementation in the food industry. This is reinforced by the triangulation of different perspectives through interviews with food producers, software vendors and consultants. Limitations of this research and suggestions for future research are outlined in the concluding chapter of this thesis.

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List of Abbreviations

APS	Advanced planning system
BDA	Big data analytics
COVID-19	Coronavirus disease 2019
ERP	Enterprise resource planning
IP	Inventory planning
IT	Information technology
KPI	Key performance indicator
MILP	Mixed-integer linear programming
MPS	Master production scheduling
PEOU	Perceived ease of use
PP&S	Production planning and scheduling
PU	Perceived usefulness
ROI	Return on investment
RTE	Ready-to-eat
SCE	Supply chain execution
SCM	Supply chain management
SCND	Supply chain network design
SCP	Supply chain planning
SME	Small and medium-sized enterprise
S&OP	Sales and operations planning
TAM	Technology acceptance model

1 Introduction

1.1 Introduction

Advanced planning systems (APS) are sophisticated software solutions to support supply chain planning (SCP). In particular, companies in the food industry can benefit from APS modules to better balance supply and demand of goods. This thesis aims to enhance the understanding of technology adoption behaviour of food companies in terms of APS.

At the beginning of this chapter, the complexity of supply chain management (SCM) in the food industry is described. Subsequently, different APS modules and software functions are explained. This is followed by an introduction of technology adoption according to Davis et al. (1989). After that, the research goal of this thesis and the three research questions are elucidated. The research approach to answer the research questions is then summarised. Lastly, the intended research contributions and the structure of the thesis are outlined.

1.2 Complexity of Food Supply Chains

SCM in the food industry is complex. In contrast to other industries, the quality of products continuously deteriorates as the products move along the supply chain (Akkerman et al. 2010). Food characteristics such as perishability and cooling requirements need to be considered to satisfy the quality requirements of consumers and to prevent food waste (Trienekens et al. 2012). The dynamics of consumer markets are ever increasing (Bowen and Burnette 2019). Consumer attitudes are constantly changing, leading to mass customisation and a growing amount of product variants (Trienekens et al. 2012). Consumer demand fluctuates depending on various factors such as price, weather, or public holidays (Khosrowabadi et al. 2022). Moreover, food supply chains have become increasingly global since consumers ask for availability of products throughout the whole year (Yu and Nagurney 2013). Food companies need to manage these global networks effectively (Trienekens et al. 2012).

The coronavirus disease 2019 (COVID-19) pandemic caused disruptions of global food supply chains. Companies had to deal with unforeseen shifts in consumer demand for food products and supply shortages (Hobbs 2020). The war in Ukraine had further adverse effects on food supply chains. In 2020 Ukraine was the world's second largest exporter of cereals (Barklie 2022). The conflict led to scarcity of raw materials and increased food prices (Jagtap et al. 2022). The global crises have amplified the need for companies in the food industry to coordinate demand and supply effectively, and to be responsive in case of supply chain disruptions (Hobbs 2020).

Therefore, SCP is essential for food companies to retain an overview of the supply chain (Ivert et al. 2015). SCP can be defined as "forward-looking process of coordinating assets to optimise the delivery of goods, services and information from supplier to customer, balancing supply and demand" (Gartner 2023). Planning problems faced by food companies can be expressed in mathematical models and solved by dedicated software tools (Liberatore and Miller 2021; Stadtler et al. 2015). APS support long-term, mid-term and short-term decision-making and ensure efficient use of resources along the supply chain (Neumann et al. 2002). Furthermore, APS enable firms to flexibly adjust plans (e.g. production schedules) and thereby enhance resilience against unexpected shifts in demand or supply shortages (Stadtler et al. 2015; Brusset and Teller 2017).

However, despite the positive impact of APS on operational efficiency, research indicates that software tools for SCP are only implemented to a limited extent in practice (Jonsson and Ivert 2015; Vlckova and Patak 2011). APS and the functions of different software modules are introduced in the following section.

1.3 Advanced Planning Systems

APS can be viewed as "add-ons" for enterprise resource planning (ERP) systems and are focused on planning tasks. ERP systems constitute the data basis for APS in most cases. ERP systems also include functions for SCP. APS incorporate more sophisticated functionalities to support SCP. The boundaries between the systems are fluent though (Stadtler et al. 2015; Lütke Entrup 2005). In contrast to ERP systems, APS provide a higher level of detail and additional simulation features (Setia et al. 2008). Moreover, APS ensure increased flexibility in case of deviations from original plans and interdependencies of planning decisions are captured in a better way. APS support supply chain planners in making decisions at different planning levels. The transactions are executed by supply chain execution (SCE) systems such as warehouse management systems and transportation management systems (Stadtler et al. 2015).

The application of APS can address the complexity of food supply chains and conflicting objectives faced by supply chain planners. APS comprise different software modules involving various functionalities and planning tasks, respectively (Stadtler et al. 2015). Figure 1.1 provides an overview of software modules that support SCP. The framework is adapted from Stadtler et al. (2015). The figure distinguishes between software modules based on the respective dimensions of the planning horizon (from transaction to long-term) and supply chain process (from procurement to sales). At the strategic level, long-term decisions about the configuration of the supply chain are met (e.g. production and warehouse locations). At the tactical planning level, demand forecasts and mid-term production planning are synchronised. Dedicated sales and operations planning (S&OP) software can support this process. Inventory planning (IP) is also carried out at this level. At the operational level, the mid-term plans are broken down into specific production and distribution plans. Supplier relationship management and order management modules serve as interfaces to suppliers and customers for integrated planning along the entire supply chain. Risks in the supply chain can be identified, assessed and reported by dedicated risk management software. In addition, software solutions in the area of supply chain visibility and business analytics can enhance transparency along the supply chain and visualise the performance of the entire supply chain using selected key performance indicators (KPIs). New digital technologies for SCP have entered the dynamic software market in recent years (Patsavellas et al. 2021). The framework can be considered as an attempt to provide an up-to-date overview of digital systems for SCP and goes beyond the software modules and decision support systems discussed by Stadtler et al. (2015) or Liberatore and Miller (2021).

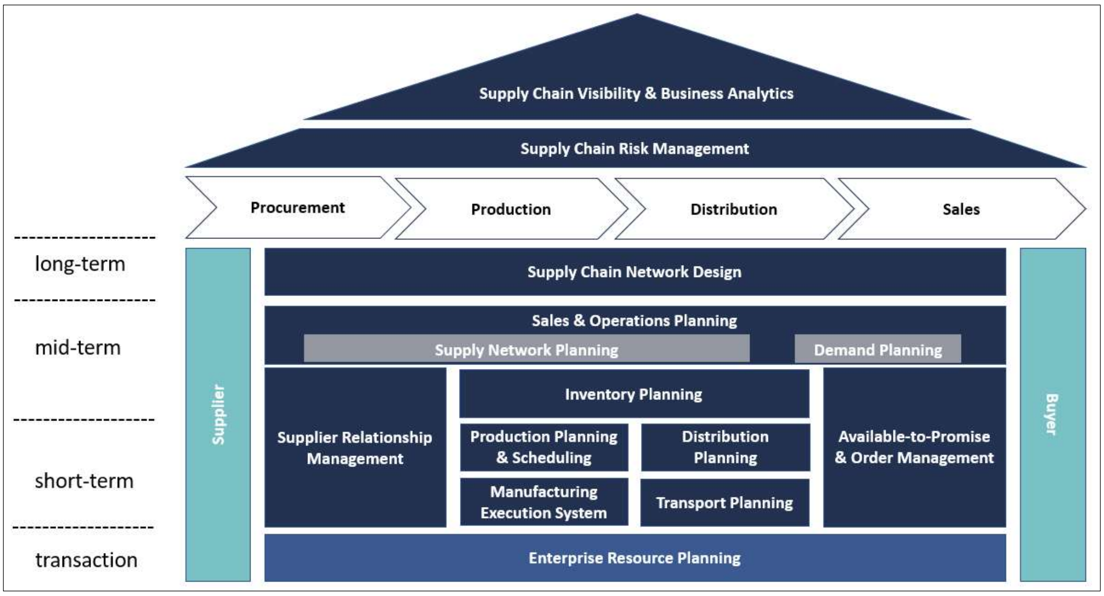

Figure 1.1: Supply chain planning & navigation framework (adapted by the author from Stadtler et al. (2015)).

The present research focuses on four APS modules, namely supply chain network design (SCND), S&OP, IP and production planning and scheduling (PP&S). Typical functionalities of the respective modules are depicted in Table 1.1. The importance of strategic decision-making has been growing in recent years. Food supply chains have become global networks responding to consumers' demand for year-round availability of products. Food products are increasingly produced, processed and distributed across different countries (Ahumada and Villalobos 2009). Consequently, decisions regarding the physical structure of the supply chain are essential for food companies.

Due to frequent new product developments, demand fluctuations and supply uncertainties, food producers require a well-functioning S&OP process to coordinate the demand- with the supply side (Ivert et al. 2015). Moreover, products and raw materials may perish if demand is not well-matched with production, reducing overall profitability (Patak and Vlckova 2012). The process can be supported either by separate demand and supply network planning modules or by an integrated software solution.

The food industry is distinct from other industries due to the perishability of products. Inventory of food producers including raw materials and finished goods can decay. The inventory needs to be planned accordingly (Shin et al. 2019).

Furthermore, complexity in PP&S is amplified due to increased product variety as a consequence of mass customisation (Trienekens et al. 2012). For instance, products may have different setup times and production equipment may need to be cleaned after production blocks (Bilgen and Günther 2010).

Table 1.1: Common functionalities of APS modules for SCND, S&OP, IP and PP&S (based on Davies et al. (2002), Wagner (2002), Ivert and Jonsson (2010), Chakraborty (2023), Shirokova and Iliashenko (2014), Akabuilo et al. (2011), and Lütke Entrup (2005)).

Module	**Functionalities**
SCND (Davies et al. 2002)	• Determination of product strategy: Includes number and main characteristics of products and markets to be served. • Determination of manufacturing strategy: Includes number and location of plants, sourcing strategy, investment decisions and supplier selection. • Determination of logistics strategy: Includes number, locations and echelons of distribution centers, sourcing strategy and investment decisions. • Determination of procurement strategy: Includes number of suppliers and selection of suppliers. • Determination of investment/divestment decisions: Includes in-/outsourcing, acquisitions/mergers and new technology introduction.
S&OP (Wagner 2002; Ivert and Jonsson 2010)	Demand planning module comprises: • Statistical forecasting: Assist the planner in making estimations derived from historical data.

	• Incorporation of judgmental factors: To correct and improve statistical forecast (e.g. by consensus of experts). • Collaborative/consensus-based decision process: Assures that input for the demand planning process can be collected from all involved departments. • Accuracy measurement: Accuracy measures such as the Mean Absolute Percentage Error (MAPE), the Mean Absolute Deviation (MAD) or the Mean Squared Error (MSE) can be used to track and evaluate forecast accuracy. Supply network planning module comprises: • Creation of unrestricted operations plan: Calculation of net demand considering inventory and comparison of production quantities with available capacities. • Bottleneck resolution: In case of bottlenecks, automated generation of a feasible plan (e.g. by building up inventory, using overtime and outsourcing or scheduling additional shifts).
IP (Chakraborty 2023; Shirokova and Iliashenko 2014)	• Inventory management: Includes features such as product categorisation, product history and stock inquiries. • Inventory level projection: Includes calculation and display of accurate inventory levels for future periods. • Inventory optimisation: Includes determination of optimal size of stocks, safety stock, reorder point, supply period, service level etc. • Order planning: Includes features such as replenishment suggestions, creation of an order plan

	and upload of order proposal data to the connected purchasing system. • Inventory tracking: Includes features such as product tracking and audit trail. • Stock-out and overstock alerts: Includes alerts in case any product is in short supply, or in excess. • Transfer management: Includes features such as multi-location tracking, order picking, kitting and product bundling. • Value added services: Includes features such as labelling and manufacturing of displays.
PP&S (Akabuilo et al. 2011; Lütke Entrup 2005)	• Dynamic lot-sizing: Definition of the quantity of an item to manufacture in a single production run. • Automated scheduling: Algorithm-based scheduling and sequencing of production orders. • Manual scheduling: To correct and improve production schedules by the input of production managers etc. • Shop floor control: Comprises methods and systems to prioritise, track, and report against production orders and schedules. • Rescheduling of orders: Enabled by drag & drop functionality in an interactive planning board.

1.4 Technology Adoption of Information Technology

APS support SCP practices in different ways. Given the complexity of food supply chains and the low implementation of sophisticated methods for SCP as indicated in previous studies (Jonsson and Ivert 2015; Vlckova and Patak 2011), it would be appealing to better understand the technology adoption behaviour of food companies in terms of APS.

Technology adoption is a well examined field of research (Lai 2017; Venkatesh et al. 2003). The technology acceptance model (TAM) by Davis et al. (1989) is a widely cited framework to elucidate the use of information technology (IT) (Venkatesh et al. 2003; Shih and Huang 2009; Masood and Sonntag 2020). The model explains the acceptance of information systems based on two determinants, namely perceived usefulness (PU) and perceived ease of use (PEOU). PU can be associated with increased effectiveness and productivity in performing a task. PEOU is related to convenient usage, intuitive interaction with the system and effortless learning of the skills to use a technology (Davis 1989; Kwahk and Lee 2008; Shih and Huang 2009). The literature provides considerable empirical support for the TAM framework (Lai 2017; Taherdoost 2018; Verma and Sinha 2018). The model has been validated and employed in various professions, for instance medicine and logistics (Walter and Lopez 2008; Chen et al. 2009). TAMs have been applied to understand technology adoption of organisations and end-users across different technologies like ERP systems (Amoako-Gyampah and Salam 2004), the internet of things (IoT) (Gao and Bai 2014) or radio frequency identification (RFID) (Lee 2009). Over the past years different versions of TAMs were developed based on the initial model by Davis et al. (1989). Multiple models have been extended by further variables to enhance their explanatory power. These include antecedents for technology acceptance such as technological, organisational or environmental factors (Venkatesh and Davis 2000; Venkatesh et al. 2003; Gao and Bai 2014; Kamble et al. 2019; Venkatesh et al. 2012; Verma and Sinha 2018). PU and PEOU are still considered as key predictors of technology adoption (Wamba et al. 2020; Verma and Sinha 2018). Treiblmaier (2019) asserts that technology adoption models should not simply be applied across different technologies. Scholars rather need to take the characteristics of different technologies and the adopting organisations into account when studying the adoption behaviour of such.

This research is focused on the technology adoption of food companies regarding APS as enabling technology for SCP. In this thesis technology adoption refers to the decision of companies to implement APS. Technology acceptance is determined by

PU and PEOU and describes the perception of decision-makers in an organisation regarding SCP software. Technology acceptance precedes technology adoption by companies (Shibly et al. 2022).

1.5 Research Goal

SCP enables companies to balance the demand for products with the supply side. Regarding the previously outlined complexity of food supply chains, SCP is particularly important for food producers (Ivert et al. 2015). Companies in the food industry are able to plan the supply chain more effectively by means of APS. Despite the benefits of APS, low implementation of sophisticated software for SCP was determined in individual studies (Jonsson and Ivert 2015; Vlckova and Patak 2011). This thesis aims to enhance the understanding of technology adoption behaviour of food companies in terms of APS. The research goal can be broken down into three research questions. In the following, the motivation of each research question is briefly explained.

SCM in the food industry is challenging due to multiple factors such as limited shelf life of food products, increasing product variety and changing consumer demand. Considering the relevance of SCP and APS as enabling technology for SCP, this research firstly aims to provide an overview of APS implementation in the food industry. The thesis thus attempts to answer the following research question:

RQ1: To what extent are APS implemented in the food industry?

PU and PEOU are well acknowledged determinants of technology adoption based on the TAM by Davis et al. (1989). This research is intended to identify antecedents of PU and PEOU of APS modules. Thereby, insights what makes APS useful and easy to use are gathered to better understand software adoption of companies. Moreover, an improved understanding of the determinants of APS adoption could contribute to a better fit between the requirements of food companies and software for SCP to ultimately enhance the application of APS modules. Therefore, this research aims to also answer the following research question:

RQ2: What are the antecedents affecting the PU and the PEOU of APS that lead to the adoption of such software tools?

APS offer several advantages for SCP as mentioned in the previous section. The adoption of APS modules does not automatically translate into the expected benefits though. Software implementations can also fail (Venkatesh and Bala 2008; Clause and Simchi-Levi 2005). Expertise how to successfully implement APS modules is thus crucial for companies. The research explores how APS implementations beyond software adoption can be enhanced. Consequently, the thesis intends to answer the following research question:

RQ3: How can APS implementations be facilitated?

1.6 Research Approach

In this section the research approach to answer the previously outlined research questions is summarised.

Firstly, a systematic literature review was conducted to examine existing literature on SCP in the food industry. The literature review was focused on SCND, S&OP, IP and PP&S. Thereby, insights regarding opportunities of SCP within food supply chains were gathered. Moreover, literature on APS implementation was investigated as sophisticated SCP relies on specialised software. Additionally, the literature concerning technology adoption in terms of APS was reviewed.

Mixed methods research was applied to answer the research questions. The explanatory sequential design consisted of a quantitative online survey and qualitative semi-structured interviews. The survey served as empirical starting point of this research. Empirical evidence regarding the level of APS implementation in the food industry was gathered by means of the survey. In addition, the usefulness of APS modules and barriers to APS adoption were queried. The survey instrument was developed after iterative discussions with the supervisors and experienced consultants in the domain of SCP. Furthermore, the survey was pretested in pilot studies. The data sample included firms from Germany, Austria, Switzerland and Italy. The survey data was analysed and presented by descriptive statistics. Different statistical tests were applied to explore differences between companies using and not using APS modules regarding supply chain complexity and company size. The survey results primarily served to answer the first research question.

In the following research phase semi-structured interviews were conducted to gain a more in-depth understanding of APS adoption. Interview participants included managers from the food industry, software vendors and consultants. Requirements for the implementation of APS modules as well as drivers and barriers to APS adoption were discussed. Furthermore, suggestions to enhance implementation projects were investigated. The interviews were prepared and carried out with academic rigour. The qualitative data was examined through thematic analysis. The interview findings were primarily used to answer the second and third research question. Subsequently, the APS adoption model was developed based on the results of the mixed methods research. The model depicts antecedents of PU and PEOU of APS and illustrates how both constructs affect the decision in organisations to adopt software for SCP. The model was validated by different experts.

Overall, mixed methods research was considered as suitable research approach to answer the research questions and to achieve the research goal. The quantitative and qualitative studies were intended to complement each other. In addition, the expert interviews were meant to provide a triangulation of different perspectives on APS adoption. The gathered insights from managers of food producers, software companies and consultants were planned to yield a holistic view on technology adoption in terms of APS.

1.7 Intended Contributions of Thesis

The thesis is intended to make different theoretical, empirical, and practical contributions. From a theoretical perspective, this research is meant to add to the existing literature on technology adoption. The research will examine technology adoption behaviour of food companies concerning APS. In particular, antecedents of PU and PEOU will be determined. Based on the findings an adapted TAM for the context of APS will be developed and validated. Different relationships will be proposed that can be investigated in future research.

The thesis is planned to make empirical contributions by means of the data gathered in the quantitative and qualitative studies of this research. The use of mixed methods research is meant to provide a broad view on APS implementation. This will be reinforced by triangulating different perspectives from food producers, software vendors and consultants in the qualitative study.

The research is further intended to make several practical contributions based on the empirical findings. The thesis is planned to give managers a better understanding of prerequisites for the introduction of APS modules, and to provide practical advice for industry players to facilitate software implementation. The research is additionally meant to contribute practical insights for software companies regarding different factors affecting the adoption of APS.

1.8 Thesis Structure

In the following section the structure of the thesis is outlined.

In Chapter 2 the literature on SCP in the food industry and APS implementation is systematically reviewed. Besides that, existing research on technology adoption in terms of APS is investigated. Furthermore, the theoretical framework for this research is introduced.

Chapter 3 presents the methodology and methods applied in this research. The philosophical foundation of this research and the research design are explained. It is further argued why mixed methods research consisting of an online survey and semi-structured interviews was selected for this research. Both methods are described in detail. This includes sample selection for the online survey, development of the survey instrument, and methods for data analysis. Similarly, the selection of interview participants, and the way how the interviews were prepared and conducted are specified.

In Chapter 4 the survey results are presented and analysed. Firstly, the data sample of the survey is outlined. The survey outcome regarding the implementation of APS modules in the food industry is put forward afterwards. Moreover, empirical evidence on the PU of APS modules and barriers to APS adoption is provided. Differences between companies using and not using APS modules to support SCP are investigated. Lastly, the survey results concerning individual software modules are put forward.

Chapter 5 summarises the interview results from the qualitative study of this research. The chapter initially gives an overview of the different interview participants. The insights from the semi-structured interviews with managers of food companies, software companies and consultants are presented thereafter. The perspectives of interview participants on system and organisational requirements for APS implementation as well as drivers and barriers to APS adoption are described. Furthermore, suggestions to improve implementation projects are outlined.

In Chapter 6 the results of the mixed methods research are discussed. This includes the discussion on the level of APS implementation in the food industry, different considerations leading to the adoption of APS, and practical advice to improve APS implementations. Based on the research findings the APS adoption model is introduced.

Chapter 7 concludes the thesis. The research findings concerning the three research questions are summarised. Implications for research and practice are outlined. Lastly, limitations of this research are explained and suggestions for further research are put forward.

2 Literature Review

2.1 Introduction

The purpose of this chapter is to improve the understanding of SCP in the food industry corresponding to the complexity of food supply chains and the resulting need for SCP. To achieve this aim, the modelling research for SCP in food companies as well as the literature on APS implementation to support SCP practices is systematically reviewed. Earlier versions of this chapter were published in Stüve et al. (2020) and Stüve et al. (2022). The literature review particularly considers the context of the application of proposed methods for SCP, indicating the practical relevance of the studies. This should provide insights into the opportunities of SCP within different food supply chains. The chapter will focus on four different planning tasks that become increasingly relevant for food companies, namely SCND, S&OP, IP and PP&S. In addition, it is examined to what extent the implementation of APS supporting long-term, mid-term and short-term decisions is covered by the research. Research on APS implementation is critical as effective SCP requires support by specific software tools. Besides that, literature regarding technology adoption in terms of APS is considered. This may provide insights into the adoption behaviour of companies concerning software tools for SCP. Similar literature reviews have been conducted by Ahumada and Villalobos (2009) and Akkerman et al. (2010). The former review concentrates on planning models for the agriculture industry; furthermore, modelling approaches are distinguished based on decision variables, and not based on APS modules. The latter review is focused on models for food distribution emphasising sustainability and food quality. This chapter presents a more holistic view on SCP in the food industry covering strategic, tactical and operational SCP models. In addition, the modelling research is contrasted with the state of literature on APS implementation.

The remainder of this chapter is structured as follows: In the next section the research approach for the literature review is specified. After that, selected research papers on SCP in the food industry are categorised based on the four planning tasks and the application context is presented. Thereafter, research papers on APS implementations are examined. This section is followed by a short review on technology adoption of APS. Insights from the literature review are discussed and the theoretical framework for this research is introduced. At the end of this chapter the findings are summarised.

2.2 Approach for Systematic Literature Review

A systematic literature review was conducted to better understand the research efforts to support more efficient food supply chains through SCND, S&OP, IP and PP&S. This method comprises the identification, selection and assessment of literature on a certain topic and ensures that research papers are analysed in a structured and repeatable way with academic rigour (Tranfield et al. 2003). The review approach pursued in this research comprises four sequential steps (Mayring 2003). Firstly, the research papers were collected. Studies for review were obtained through Scopus and Google Scholar databases and snowballing of citations in relevant papers. Both databases have often been utilised for literature reviews in the domain of SCM and are well acknowledged sources to gather relevant literature (Hosseini et al. 2019; Asl et al. 2021; Talwar et al. 2021). Keywords used are “food industry”, “supply chain planning”, “advanced planning systems”, “supply chain network design”, “strategic network planning”, “sales & operations planning”, “demand planning”, “supply network planning”, “inventory planning”, “production planning & scheduling”, “production planning” and “production scheduling”. Boolean keyword search was applied to retrieve the research papers (see Table 2.1). The search string was used to ensure that the gathered papers are related to planning decisions in one of the specific areas of SCP in the context of a food producing company. Studies published between 1998 and 2022 in peer-reviewed journals were considered. In 1998 SAP APO was introduced as software for integrated business planning.

Table 2.1: Boolean keyword search applied for systematic literature review (based on author's own research).

Area of SCP	Boolean search terms
SCND	"supply chain network design" OR "strategic network planning" AND "supply chain planning" OR "advanced planning systems" AND "food industry"
S&OP	"sales & operations planning" OR "demand planning" OR "supply network planning" AND "supply chain planning" OR "advanced planning systems" AND "food industry"
IP	"inventory planning" AND "supply chain planning" OR "advanced planning systems" AND "food industry"
PP&S	"production planning & scheduling" OR "production planning" OR "production scheduling" AND "supply chain planning" OR "advanced planning systems" AND "food industry"

Only papers addressing SCP practices of food companies that can be associated with SCND, S&OP, IP and PP&S were selected. Figure 2.1 illustrates the process of how the final 117 peer-reviewed research papers were selected. Secondly, collected studies were examined based on year of publication, author, and publishing journal. Papers with the same author, title, volume, issue, and publication date were considered as duplicates and were thus excluded. Thirdly, studies were categorised according to the four mentioned fields of SCP. Lastly, the individual modelling approaches for SCP of the collected research papers were presented. Characteristics of the targeted food supply chain, including the product and country under consideration, were depicted to indicate the practical relevance of the selected modelling research. Moreover, the methods underlying the respective models were determined. The review further includes an analysis of the literature covering the implementation of APS to support SCP in food companies, as modelling approaches for SCP are normally solved by specialised software modules. Overall, the review of modelling approaches for SCP within food companies and of research on APS implementation as an enabler of SCP should give an indication of the current state of the literature regarding SCP in the food industry. The systematic literature review was initially conducted in 2020 and was updated at the beginning of 2023.

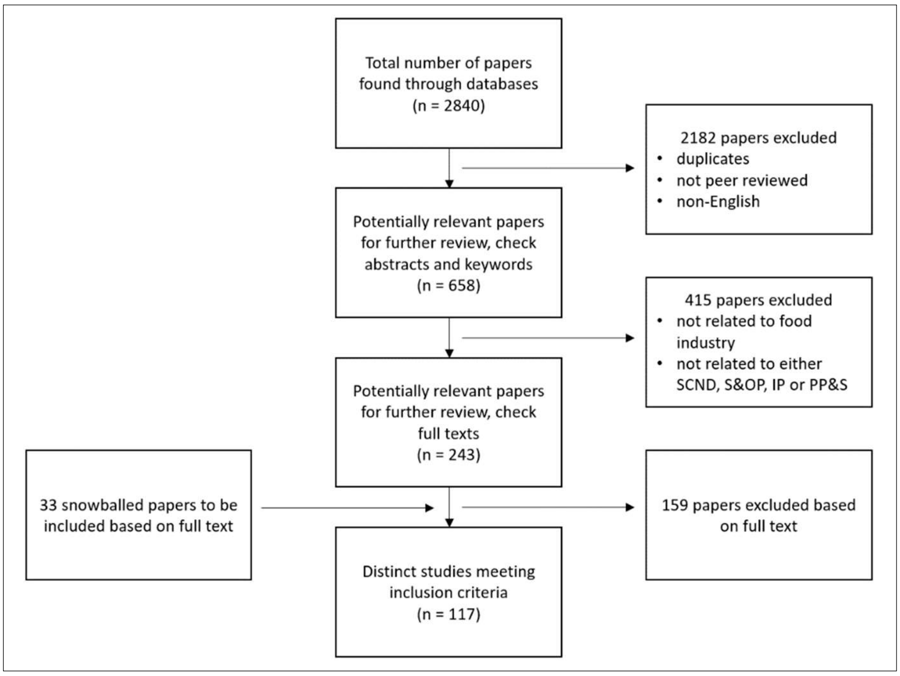

Figure 2.1: Flow diagram of paper selection and inclusion/exclusion process (based on author's own research).

2.3 Research Segmentation and Overview

In this section, collected studies are examined based on year of publication, author, and publishing journal. The final list of papers that could be identified through Scopus and Google Scholar comprises 117 peer-reviewed research papers that deal with SCP within the food industry supporting either of the four planning tasks under consideration. In this chapter, only a part of the selected papers will be presented as an illustrative example; the full list can be requested from the author.

2.3.1 Distribution of Papers over the Years

In total 27 studies can be categorised as belonging to the domain of SCND. 19 papers are associated with mid-term SCP supporting the S&OP process. 26 studies are related to IP. The majority of the identified literature, comprising 45 research papers, is aimed at enhancing PP&S. Overall, there was a growing interest in this kind of SCP research till 2012, with a decline in published research papers in the past ten years (see Figure 2.2).

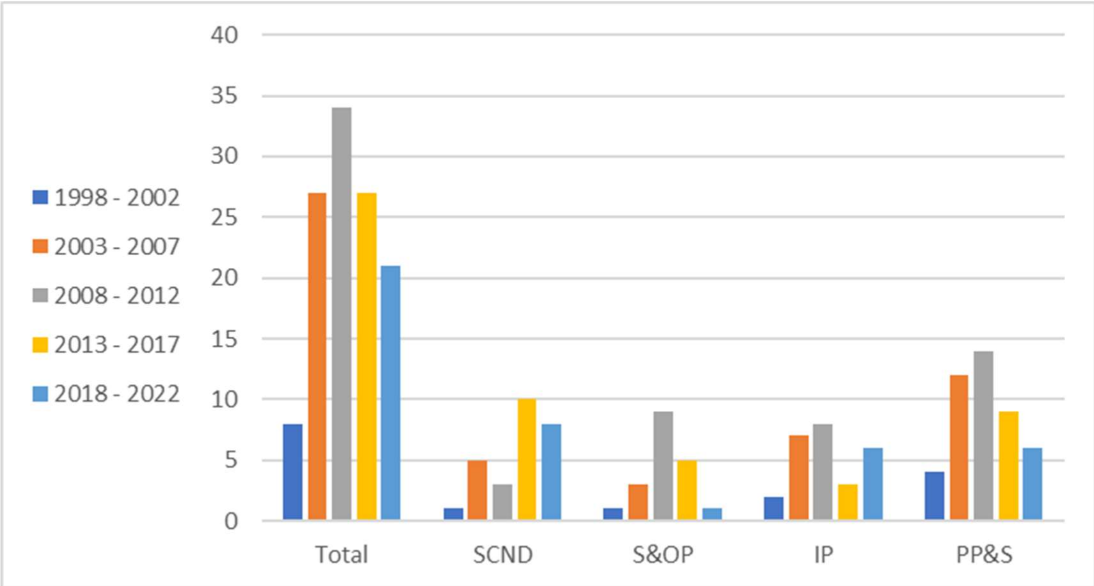

Figure 2.2: Distribution of papers over time (based on author's own research).

2.3.2 Contributions classified by Author

In total 276 scholars have contributed to the 117 selected research papers for this literature review. Akkerman, Bilgen, Grunow and Georgiadis are among the top contributing authors to the domain of SCP in the food industry (see Figure 2.3). While Akkerman can be associated with five papers, Bilgen, Grunow and Georgiadis are involved in four studies published in peer-reviewed academic journals.

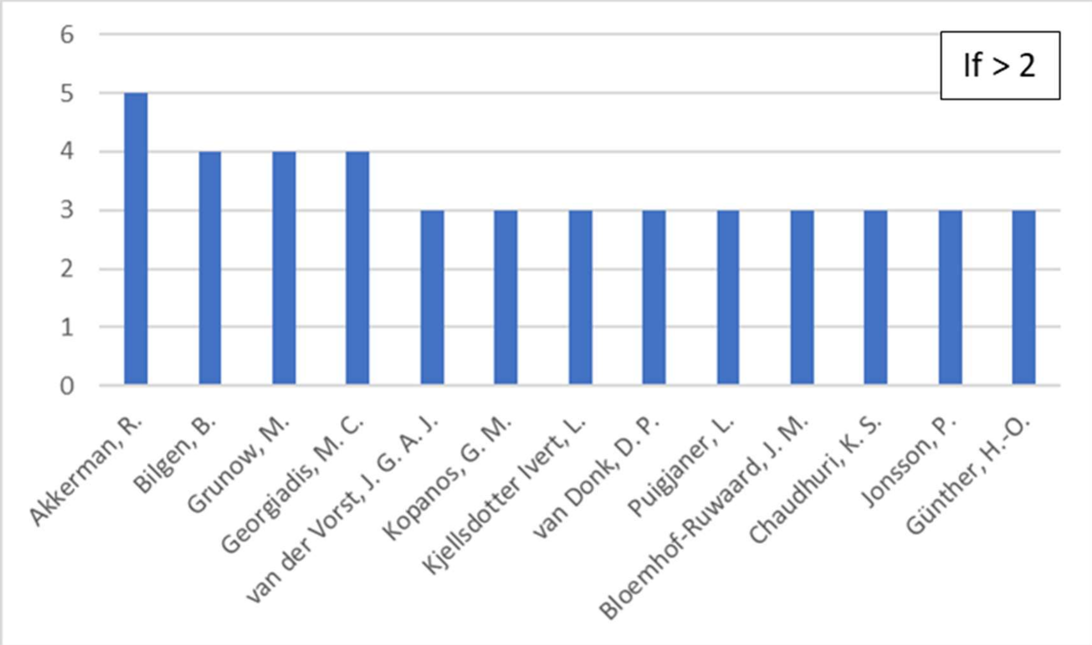

Figure 2.3: Contributions classified by author (based on author's own research).

2.3.3 Contributions classified by Journal

Research papers are selected from 53 different academic journals. Among the various journals, International Journal of Production Economics, International Journal of Production Research and European Journal of Operational Research provided the most contributions in the focused areas of SCP for the food industry (see Figure 2.4).

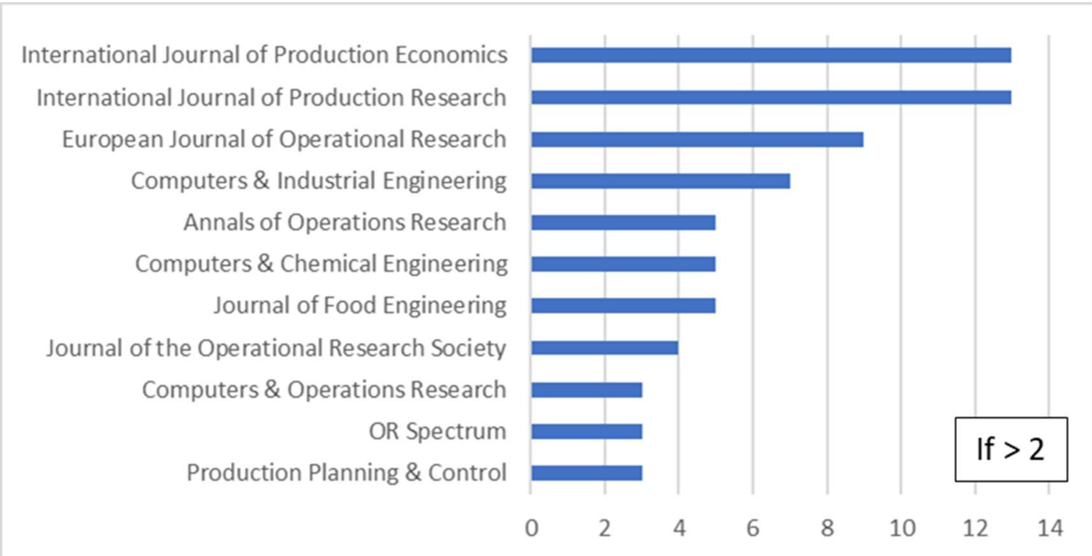

Figure 2.4: Contributions classified by academic journal (based on author's own research).

2.4 Classification based on Problem Context

In this section, the individual modelling approaches that can be associated with SCND, S&OP, IP and PP&S are presented. Characteristics of the targeted food supply chain are depicted to indicate the practical relevance of the selected modelling research. The review of the modelling research for SCP is followed by an analysis of the literature covering the implementation of APS to support SCP in food companies, as modelling approaches for SCP are normally solved by specialised software modules.

2.4.1 Supply Chain Network Design

Multiple scholars have studied strategic decisions relating to the supply chain design of specific companies in the food industry (see Table 2.2). Most of these scholars elaborated models using mixed-integer linear programming (MILP) methods to optimise the configuration of the supply chain. Hosseini-Motlagh et al. (2019), for instance, developed a model enabling a reduction of total costs of a supply chain network. The mathematical model is validated by real data of the wheat supply chain network in Iran and integrates choices regarding location and capacities for silos as well as the selection of transportation modes. Furthermore, different models have been formulated to meet strategic investment decisions. Aras and Bilge (2018) developed a model for a company producing snacks in Turkey. Their model supports long-term decisions concerning the location and timing of a new production facility, capacities and the assignment to customers. Likewise, Wouda et al. (2002) studied the supply chain network of a company operating in the Hungarian dairy industry. Their model is supposed to ascertain the most efficient network design after the acquisition of multiple companies in that industry. Musavi and Bozorgi-Amiri (2017) proposed a hub scheduling model for perishable food supply chains. The approach ensures that the quality requirements of customers are met while overall transportation costs and carbon emissions of vehicles are reduced. Similarly, Mohammed and Wang (2017) investigated a three-echelon meat supply chain and presented a model that involves multiple objectives. The model aims to minimise transportation costs, the number of vehicles needed as well as delivery time, and identifies the optimal number of farms and abattoirs. Further methods have been developed by scholars to optimise material flow within a supply chain network. The model formulated by Khalili-Damghani et al. (2014) considers a multi-objective supply chain under uncertain conditions and is validated by a case study of a seafood producer in Iran. Reiner and Trcka (2004) suggest a product specific supply chain design model. Their model is applied and verified in a case study of a pasta manufacturer. Several authors formulated approaches to include environmentally conscious thinking in their multi-objective models for strategic decision making. Colicchia et al. (2016), for example, developed a framework to balance their economic and ecological impact, such as the carbon footprint of a company's distribution network. Their model could be verified based on a case study of a chocolate producer in Italy.

Table 2.2: Example models for SCND (based on author's own research).

Paper	**Product**	**Country**	**Method**
Hosseini-Motlagh et al. (2019)	Wheat	Iran	Stochastic programming
Aras and Bilge (2018)	Snacks	Turkey	MILP
Musavi and Bozorgi-Amiri (2017)	Perishable food	-	MILP
Mohammed and Wang (2017)	Meat	UK	Multi-objective robust possibilistic programming
Colicchia et al. (2016)	Chocolate	Italy	MILP
Khalili-Damghani et al. (2014)	Seafood	Iran	MILP

Reiner and Trcka (2004)	Pasta	-	Simulation
Wouda et al. (2002)	Dairy	Hungary	MILP

2.4.2 Sales & Operations Planning

Academics have also developed modelling approaches for S&OP in the food industry (see Table 2.3). In their research Nemati et al. (2017) compared a fully integrated, a partially integrated, and a traditional decoupled S&OP approach. The different methods were defined by multi-integer programming models. A case study in the dairy industry revealed a superior performance of the fully integrated S&OP approach over the other two models. The model by Liu and Nagurney (2012) helps managers to maximise profits while considering the interplay of different decision-makers in a competitive supply chain network. Thus, an equilibrium pattern can be calculated including inventories, prices of products and transactions. Various approaches for demand forecasting exist. Time-series-analysis methods are solely based on past demand assuming patterns of demand over time. The most frequently used methods are the simple moving average and the exponential smoothing method. Causal models assume that demand is influenced by several known factors like weather or temperature (Stadtler et al. 2015). Cheikhrouhou et al. (2011) developed a forecasting approach that enables demand planners to adjust mathematical forecasts based on their implicit knowledge regarding future events (special offers, opening of new stores, etc.) in a structured way. The approach was validated in a case study with a company from the fresh food industry. The forecast accuracy could be enhanced by the structured integration of the expertise of forecasters to the mathematical forecast.

Supply network planning represents another essential step within the sales & operations process that can be supported by APS. Multiple models have been formulated to address uncertainties on the supply side of the supply chain. Rong et al. (2011) developed a multi-objective method that can be applied for production and distribution planning. Their approach considers economic factors and explicitly models the quality of food products based on the temperature of products during storage and distribution. Thereby, food waste within the distribution network can be reduced. The model is validated in a case study of a supply chain for bell peppers. Likewise, Ahumada and Villalobos (2011) proposed a model for tactical production and distribution planning for a fresh produce grower in Mexico. The perishability of products is taken into account by a loss function and by limiting the storage time. Higgins et al. (2006) formulated a tool to establish an annual schedule for the production and shipping of sugar in Australia. The complexity of the sugar supply chain in Australia stems from the multitude of sugar brands that are produced in different mills and from ships that need to be assigned to the ports while complying with the storage constraints of the individual ports. The authors argue that production and shipping costs could be significantly reduced based on the proposed model. Furthermore, Ioannou (2005) reports on a reorganisation project in which the distribution network of a Greek sugar producer could be optimised. Newly developed transportation models resulted in essential savings for the company. The method by Sel et al. (2015) supports integrated tactical and operational decision-making for PP&S. A heuristic is proposed to decompose mid-term planning into short-term scheduling of yoghurt production.

Table 2.3: Example models for S&OP/demand planning/supply network planning (based on author's own research).

Paper	**Product**	**Country**	**Method**
Nemati et al. (2017)	Dairy	Iran	MIP
Sel et al. (2015)	Yoghurt	-	MILP & heuristic
Liu and Nagurney (2012)	Perishable food	-	Algorithm
Ahumada and Villalobos (2011)	Bell peppers & vine ripe tomatoes	Mexico	MILP
Cheikhrouhou et al. (2011)	Fresh food	-	Fuzzy inference system

Rong et al. (2011)	Bell peppers	-	MILP
Higgins et al. (2006)	Sugar	Australia	MILP & heuristics
Ioannou (2005)	Sugar	Greece	LP

2.4.3 Inventory Planning

The review of the literature also revealed multiple models for the management of inventories in food supply chains (see Table 2.4). Takey and Mesquita (2006) developed a model to optimise the inventory management of a large ice cream manufacturer in Brazil. The company had to cope with high seasonal demand which led to high inventory levels and inefficient operations. The authors created an aggregated planning model with a planning horizon of 12 months. The outcome of the tool had to be reviewed monthly. It is argued that the use of the approach contributes to lower inventory levels of finished and unfinished goods at the ice cream manufacturer. Teerasoponpong and Sopadang (2022) established a machine learning technique to improve sourcing and inventory management decisions. The developed tool can, for example, support supplier selection and determining optimal order quantities. The system was targeted for small and medium-sized enterprises (SMEs) dealing with uncertain demand, lead times, and supply costs. The approach could be validated in a case study of a pastry company in Thailand. Muriana (2016) developed an Economic Order Quantity (EOQ) model for perishable food assuming stochastic demand. Besides the perishability of products, the probability that an item is not sold before the end of its shelf life is considered in the model. Hsiao et al. (2017) developed an approach for the inventory management of ready-to-eat (RTE) food. By means of the model food quality and remaining food value of food products can be quantified considering the deterioration rate and different storage temperatures. The tool can be used as guidance for inventory practices of temperature-controlled supply chains according to the authors. Another approach established by Bozorgi et al. (2014) takes the emissions of cold supply chains into account. Based on the model optimal order quantities can be calculated while transportation and holding costs as well as emissions are minimised. Likewise, an IP model for a three-echelon meat supply chain comprising breeding centers, abattoirs, and retailers was developed by Gholami-Zanjani et al. (2021). The proposed model optimises the replenishment of meat considering environmental factors and the impact of disruptions. Shin et al. (2019) studied an inventory management problem related to the two-phased manufacturing process of kimchi. A model was formulated by the authors that incorporates the perishability of kimchi as well as the salting process leading to an extended shelf life of the raw cabbage. The objective of the model is to align supply and demand quantities. The research by Qiu et al. (2019) provides a tool that jointly optimises production, inventory, distribution and routing decisions with perishable inventory. The model was validated based on the case study of a Chinese meat manufacturer.

Table 2.4: Example models for IP (based on author's own research).

Paper	**Product**	**Country**	**Method**
Teerasoponpong and Sopadang (2022)	Pastry	Thailand	Artificial neural network, genetic algorithm
Gholami-Zanjani et al. (2021)	Meat	-	MILP
Qiu et al. (2019)	Fresh meat	China	MILP
Shin et al. (2019)	Kimchi	Korea	MIP
Hsiao et al. (2017)	RTE food	Taiwan	Fuzzy model
Muriana (2016)	Perishable food	-	Stochastic model
Bozorgi et al. (2014)	Frozen food	-	Non-linear model
Takey and Mesquita (2006)	Ice cream	Brazil	LP

2.4.4 Production Planning & Scheduling

Several modelling approaches have also been developed for PP&S of food products (see Table 2.5). Doganis and Sarimveis (2008), for instance, formulated a method to optimise yoghurt production. The approach ensures efficient use of resources and captures the increased complexity of an enlarged product portfolio. Thus, multiple variables such as fat content of products, processing times, diverse due dates and sequence-dependent setup times are considered. Similarly, Bilgen and Dogan (2015) created a MILP model targeted towards multistage production in the dairy industry. The proposed method determines the optimal timing and quantity of intermediates and final products to be produced over a specific time period. A further approach covering the uncertainty of milk supply has been developed by Guan and Philpott (2011) to support the production planning of a dairy company in New Zealand. Lütke Entrup et al. (2005) integrated shelf life in their models for weekly planning of yoghurt production. The approach by Wari and Zhu (2016) addresses the multi-week production scheduling of ice cream. The model can be used to optimise makespan and includes several constraints such as clean-up sessions and weekend breaks. A method by Kilic et al. (2013) is formulated to solve the blending problem of a flour manufacturer. The tool helps to determine the optimal blending of intermediates to minimise operational costs. Amorim et al. (2012) elaborated an approach for integrated production and distribution planning considering freshness of perishable products besides economic objectives. It is shown that the integrated method contributes to significant savings compared to the decoupled approach, although savings compared to the traditional method decrease the higher the freshness standards. Wauters et al. (2012) developed a specialised scheduler that can be integrated in a manufacturing execution system. The proposed approach enables food processing companies to schedule different production orders at the same time. The routing of production orders within a plant layout is optimised. Thereby, the makespan and the quality of the overall production process is enhanced considering the variety of products.

Table 2.5: Example models for PP&S (based on author's own research).

Paper	**Product**	**Country**	**Method**
Wari and Zhu (2016)	Ice cream	-	MILP
Bilgen and Dogan (2015)	Dairy	-	MILP
Kilic et al. (2013)	Flour	-	MILP
Amorim et al. (2012)	Perishable food	-	MIP & MINLP
Wauters et al. (2012)	-	-	Algorithm
Guan and Philpott (2011)	Dairy	New Zealand	Stochastic quadratic model & algorithm
Doganis and Sarimveis (2008)	Yoghurt	Greece	MILP
Lütke Entrup et al. (2005)	Yoghurt	-	MILP

2.5 Implementation of Advanced Planning Systems

The literature examined before covers multiple mathematical models that are targeting certain planning problems in different food supply chains. Typically, such models are integrated into APS to enhance supply chain efficiency. Despite the complexity of food supply chains and the related significant potential benefits from implementing advanced planning solutions, literature on the implementation of APS is sparse (see Table 2.6).

A few studies have investigated the utilisation of planning software in food companies. Vlckova and Patak (2011) examined the demand planning practices of four companies including a food company. Their study revealed that demand planning in the food company was performed via Excel spreadsheets. According to the authors, effective demand planning involves collaboration across different departments. It is argued that this could be only achieved by utilising integrated information systems. Likewise, Jonsson and Ivert (2015) found through a survey among Swedish manufacturing companies, including 30 responses from the food industry, that only a small amount of companies were using sophisticated methods for master production scheduling (MPS). They found a positive effect on supply chain performance from the application of planning software for MPS. It is argued that advanced methods would lead to more feasible plans.

There are also a few case studies documenting the implementation of APS modules in specific companies. Mickein et al. (2022) investigated the introduction of a production planning system at a Swiss brewery. The study revealed different benefits of the implemented system. The software contributed to increased planning quality leading to a reduction of production costs. Moreover, planning effort for production planners could be minimised. Similarly, Zago and Mesquita (2015) conducted a case study at a Brazilian dairy company to assess the benefits and risks of the implementation of S&OP software. The study confirms greater planning accuracy providing enhanced control over inventory levels, reduced transportation costs and the opportunity for scenario analysis as the main benefits of the software. Top management support and system integration are mentioned as major challenges in the implementation project. In other research by Brown et al. (2001), the authors describe the application of a planning software by the Kellogg Company to support short-term as well as mid-term decisions. The system is used for weekly production and distribution schedules and monthly decisions on the production capacity of the different plants. According to the authors, production, inventory and distribution costs could be strongly reduced by the implemented system. Rudberg and Thulin (2009) conducted a further case study in the agriculture industry. It highlights that efficiency along the supply chain can be significantly increased by the use of a master planning module. Higher throughput at lower cost and an improved service level combined with lower inventory were observed as major benefits of the software.

Further case studies of APS implementation with more complex supply chain structures are recommended by the authors.

Jonsson et al. (2007) conducted explorative case studies of three companies using APS, including two companies from the food industry. One of them, a producer of vegetable oils and fats, implemented a software module for SCND after a merger to analyse the utilisation of two production sites and the impact on logistics costs, based on different scenarios. The other company from the grocery industry introduced a new tool for centralised mid-term supply chain master planning. Both cases reveal enhanced collaboration across different functions and increased commitment to the developed plans as major benefits of APS implementation. A further study examined three companies, among them a food and a brewery company, implementing software for tactical production planning. Three different types of problems that occur during implementation projects could be identified, namely, process-, system- and plan-related problems. Process-related problems are associated with difficulties to achieve progress within the project. System-related problems refer to not using the full potential of the software module. The generation of unrealistic plans by the software is considered a plan-related problem. Various propositions regarding the causes of such problems are provided by the authors (Ivert and Jonsson 2011).

Table 2.6: Research papers on APS implementation in the food industry (based on author's own research).

Paper	**Method**	**Objective**
Mickein et al. (2022)	Case study of a Swiss brewery	Examine the implementation of a decision support system for production planning
Jonsson and Ivert (2015)	Survey among Swedish manufacturing companies from different industries (including food & beverage)	Determine the impact of different MPS methods on company performance

Zago and Mesquita (2015)	Case study of a dairy company	Examine the benefits of using an APS module for S&OP and determine success factors for the implementation of an APS module
Ivert and Jonsson (2011)	Three case studies of manufacturing companies (including a food and a brewery company)	Investigate problems encountered in the different phases of implementation projects of software tools to support tactical production planning
Vlckova and Patak (2011)	Interviews with managers from four companies (including one company from the food industry)	Investigate demand planning practices and the use of software to support demand planning
Rudberg and Thulin (2009)	Case study of a company from the farming & food industry	Examine how master planning can be enabled by an APS module
Jonsson et al. (2007)	Three case studies (including two cases from the food industry)	Examine the use and perceived impact of the application of APS modules for strategic network planning and MPS
Brown et al. (2001)	Case study of a company producing cereals and convenience food	Examine the effects of using software supporting tactical and operational SCP

2.6 Technology Adoption and Advanced Planning Systems

Regarding the limited implementation of APS in practice (Jonsson and Ivert 2015; Vlckova and Patak 2011) it would be appealing to understand the adoption behaviour of organisations with respect to APS. Literature regarding technology adoption related to APS is rare, though. The literature search by Google Scholar using the keywords “technology adoption” and “advanced planning system” yields 47 papers. Similarly, “technology acceptance” and “advanced planning system” result in 32 papers. Nonetheless, the literature search including snowballing of citations reveals no peer-reviewed research papers that analyse the factors influencing the usage of APS. The majority of the resulting papers analyse the adoption behaviour of technologies such as ERP systems, blockchain technology or examine challenges with regard to the implementation of supply chain analytics in general. Based on an adapted TAM Masood and Sonntag (2020) investigated benefits and challenges regarding the implementation of Industry 4.0 technologies in SMEs. Different authors studied the factors influencing the adoption of blockchain technology in supply chains (Kamble et al. 2019; Wamba et al. 2020). Faisal and Idris (2020) investigated the determinants of supply chain technology adoption in a survey among 106 SMEs from diverse industries in Malaysia. Likewise, Verma and Chaurasia (2019) studied the adoption of big data analytics (BDA) based on a survey among 231 managers. Puklavec et al. (2018) empirically analysed the influence of technological, organisational and environmental factors on the different adoption stages of business intelligence systems. For their study, the authors considered data of 181 SMEs. Jeyaraj et al. (2006) examined 48 studies on individual IT adoption and 51 studies on organisational IT adoption in a literature review. Similarly, Arunachalam et al. (2018) conducted a systematic literature review on the capabilities needed for the implementation of BDA in SCM.

2.7 Theoretical Framework

In this section the theoretical framework for this research is presented. The theoretical framework provides explanations for the low implementation of APS and served as guidance for this research. Companies are increasingly analysed in terms of their processes. The concept of process maturity has gained importance in research. The term suggests that processes can be evaluated based on how well a process is defined, managed, measured and controlled (Lockamy III et al. 2008). Overall, research agrees that a higher process maturity is linked to increased company performance (Lockamy III and McCormack 2004; Clause and Simchi-Levi 2005). SCP is defined as a forward-looking process to coordinate the supply with the demand side (Gartner 2023). Various process maturity frameworks for individual planning practices such as S&OP (Grimson and Pyke 2007; Thomé et al. 2012) or MPS (Jonsson and Ivert 2015) exist. While some authors consider IT as enabling element for mature planning processes (Grimson and Pyke 2007), software tools are regarded as key drivers for advanced planning practices by others (Lapide 2005; Jonsson and Ivert 2015). Overall, it is agreed that IT software is a critical factor for mature SCP processes. Software companies have developed APS that incorporate mathematical and statistical models to ensure optimised plans (Lin et al. 2007; Tenhiälä 2011). SCP is particularly relevant for food companies due to the increasing complexity of food supply chains (Akkerman et al. 2010; Trienekens et al. 2012). However, research indicates that mature SCP is scarce and APS are only implemented to a limited extent in practice (Jonsson and Ivert 2015; Vlckova and Patak 2011; Tate et al. 2015).

Jonsson and Holmström (2016) determined a gap between research and practice regarding literature in the domain of SCP. Several weaknesses of research in that field were identified. It is criticised that research does not provide an understanding of how intended and unintended outcomes of SCP are accomplished. According to Jonsson and Holmström (2016), there is also a lack of literature on the challenges of implementing SCP in an organisation and the context of SCP practices is neglected. It is further argued that outcomes are predominantly demonstrated in the form of optimised models, whereas empirical evidence on outcomes of SCP is limited. The scholars follow that research on SCP is not actionable for practitioners and demand field-tested SCP theory. The concept of field-tested academic management research has been put forward by van Aken (2004). The author called for more prescription-driven research to increase the relevance of management research. This literature review complements well with the analysis of Jonsson and Holmström (2016). The review of the literature focused on four areas of SCP within the context of the food industry and underpins their findings. Multiple modelling approaches have been customised for diverse food supply chain settings. The implementation of such models in practice remains unclear though. The literature review further revealed that research lacks explanations for the adoption behaviour of companies with respect to software for SCP. Scholars were less interested in developing further planning models for S&OP and PP&S in recent years (see Figure 2.2). A reason for this could be that the modelling research in these areas is saturated. Scholars may have also realised that this research is only appreciated by a small amount of companies that could apply the models in practice.

The theoretical framework illustrated in Figure 2.5 gives explanations for the low implementation of APS and guided this research. Regarding the significance of sophisticated software for SCP practices, research on the implementation of planning tools is overdue. Insufficient IT infrastructure being a major driver for mature SCP practices may be an explanation for the less advanced planning practices within food companies. Sophisticated SCP can contribute to enhanced operational efficiency along a supply chain, but also to ecological benefits such as reduced carbon emissions and food waste (Rong et al. 2011; Colicchia et al. 2016). Therefore, it is critical to generate a better understanding of the PU and PEOU of software tools for SCP. In particular, antecedents of PU and PEOU of software tools for SCP will be explored in this research. The insights will be highly valuable for practice. Managers may acknowledge PU and PEOU as key determinants of technology adoption. Practitioners may be even more interested in the question what makes APS useful and easy to use though (Lee et al. 2003). This will lay the foundation to create a better fit between the needs of the food industry and the feature set of APS tools to ultimately enhance the application of APS modules and thereby increase the efficiency of food supply chains in the future.

Different factors may impact the PU of software tools for SCP. It is emphasised in the literature that the difficulty of SCP is reinforced in complex supply chains (Soares and Vieira 2009; Tenhiälä 2011). Advanced planning practices can generate more feasible plans for the supply chain (Jonsson and Ivert 2015). Setia et al. (2008) highlighted that technology adoptions need to be well-considered and technologies should fit with the overall organisation. Companies may not benefit from the new software, if the supply chain is less complex and managers do not require technological support for their decisions as a consequence (Setia et al. 2008; Tenhiälä 2011). The functionalities of APS can also be considered insufficient. Likewise, software tools may be rejected due to missing functions that would be required for business operations (Stadtler et al. 2015; Ivert and Jonsson 2011). In addition, software tools for SCP need to be customised to organisational characteristics (e.g. multi-echelon supply chain) (Shang et al. 2008; Zoryk-Schalla et al. 2004; Setia et al. 2008). If company requirements cannot be covered, the PU of software solutions is most likely reduced.

The PEOU of APS may be similarly influenced by different variables. Companies may decide against software implementation due to bad data quality (Hazen et al. 2014). APS mostly rely on master data provided by the organisation. Accessing data from different departments in an organisation can be challenging, and the validation of data, as well as data cleansing, can be time-consuming (Richey Jr et al. 2016; Ivert and Jonsson 2011). Lack of expertise could also prevent companies from implementing new software. Organisations may not have employees with the necessary educational background or analytical capabilities to handle such systems (Richey Jr et al. 2016). Skills and expertise in a company are recognised as key factors for successful technology implementation (Schoenherr and Speier-Pero 2015; Richey Jr et al. 2016; Ivert and Jonsson 2011). Additionally, external expertise can be obtained by consultancies. These can provide training and support to the business (Ivert and Jonsson 2011). Know-how may increase a company’s endeavour for new software. Furthermore, the integration of a new system is a critical factor for software implementation. Case studies confirm that the integration of new software with existing IT infrastructure can be challenging (Zago and Mesquita 2015; Wiers 2002). Thus, complex interfaces may reduce managers’ PEOU of new systems.

Management support is emphasised as a critical requirement for technology adoption by organisations in literature (Zago and Mesquita 2015; Jeyaraj et al. 2006). PU and PEOU are expected to positively influence management support. Having determined the usefulness and ease of use of a system, upper management decides whether to contribute resources to a particular implementation project and finally adopt software for SCP.

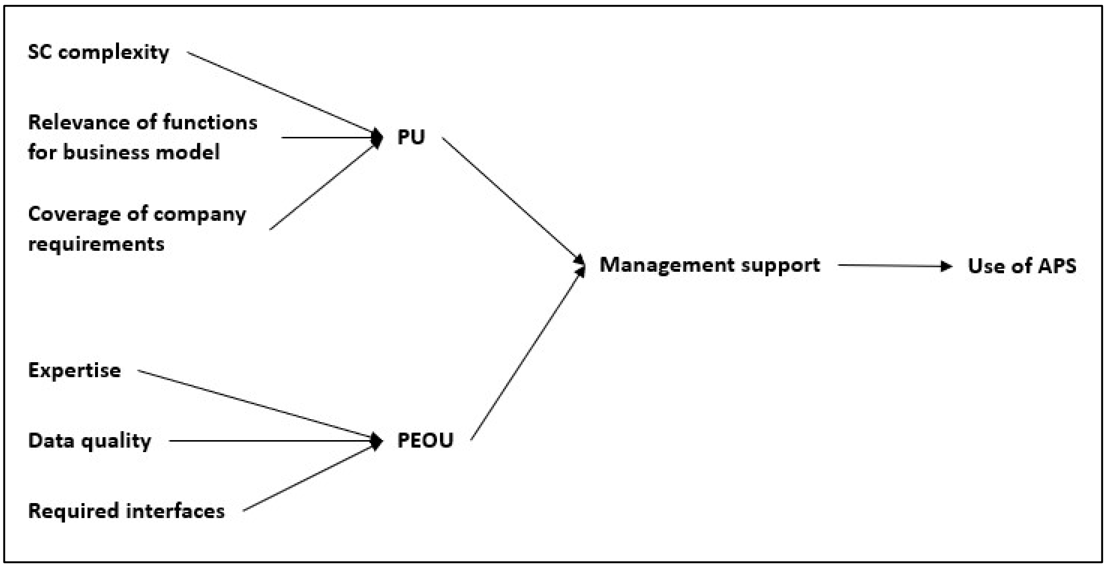

Figure 2.5: TAM of APS (adapted by the author from Davis et al. (1989)).

Based on the adapted TAM nine propositions are developed that will be investigated further in this research.

1) An increase in supply chain complexity is expected to have a positive impact on the PU of software tools for SCP.
2) Greater relevance of APS functions for the business is expected to have a positive impact on the PU of software tools for SCP.
3) Greater coverage of company requirements is expected to have a positive impact on the PU of software tools for SCP.
4) Greater expertise within an organisation is expected to have a positive impact on the PEOU of software tools for SCP.
5) Greater data quality is expected to have a positive impact on the PEOU of software tools for SCP.
6) An increase in the complexity of required interfaces is expected to have a negative impact on the PEOU of software tools for SCP.

7) Enhanced PU of software tools for SCP practices is expected to have a positive impact on management support for new software.

8) Enhanced PEOU of software tools for SCP practices is expected to have a positive impact on management support for new software.

9) Greater management support for the use of software tools for SCP practices is expected to have a positive impact on the adoption of these systems.

The propositions provide explanations for an enhanced understanding of the adoption behaviour of food companies regarding software tools for SCP. This may provide insights why companies largely refrain from implementing software for SCP in spite of the great modelling effort in that research domain. It is noteworthy that technology adoption does not automatically translate into promised benefits. The extent of software usage, support inside an organisation and further factors can limit the positive impact of an implemented technology (Setia et al. 2008). The initial phase within an implementation project is still considered critical for successful software implementation (Ivert and Jonsson 2011).

2.8 Chapter Summary

This literature review aimed to address the academic efforts by scholars on SCP and the use of APS to support SCP practices. The review has shown that multiple mathematical models of operations research have been developed and customised to complex planning problems within food supply chains. Academics have formulated diverse modelling approaches to support decisions relating to SCND, S&OP, IP and PP&S, taking account of the specifics in different food sectors around the world. The methods are intended to help practitioners to deal with conflicting objectives, a multitude of decision alternatives and uncertainty. Furthermore, a growing number of models have been developed for integrated planning across decision levels (Omar and Teo 2007; Amorim et al. 2012). The applicability of mathematical models is emphasised by scholars. While most methods are validated by real data, the implementation in practice of a large part of modelling approaches remains vague.

The present review has revealed that empirical investigations regarding the implementation of such software are limited to a few case studies. This is unlike research on other IT software such as ERP systems (Momoh et al. 2010; Hong and Kim 2002). The implementation of ERP systems differs from APS implementation though (Wiers 2002; Ivert and Jonsson 2011). Existing research predominantly reports on the benefits of APS (e.g. lower inventory levels) (Zago and Mesquita 2015). Those studies examining whether APS modules have actually been implemented found either no utilisation or less advanced methods of SCP (Vlckova and Patak 2011; Jonsson and Ivert 2015).

The review of the literature has further uncovered a lack of research regarding APS adoption. A majority of the examined literature is concerned with the adoption behaviour regarding technologies such as ERP systems, blockchain technology or investigates challenges associated with the implementation of supply chain analytics in general. Considering the positive effect that APS could have on the efficiency of food supply chains, a better understanding of technology adoption behaviour of food companies in terms of APS is needed. Firstly, this thesis is planned to establish an overview of APS implementation in the food industry given the limited empirical studies on APS adoption in previous literature. Secondly, the research is intended to identify antecedents of PU and PEOU regarding SCP software. The developed theoretical framework gives explanations for the low implementation of APS. The antecedents of APS adoption will be investigated further throughout this research. Thirdly, the research is meant to provide practical advice how the implementation of APS beyond software adoption can be facilitated. The methodology and methods to achieve these research objectives are explained in the following chapter.

3 Methodology

3.1 Introduction

This chapter informs about the methodology and methods applied in this research. First of all, the philosophical foundation of this research will be explained. After that, the research design will be presented. For this research a mixed methods explanatory design is used. The mixed methods design comprises a quantitative survey and qualitative semi-structured interviews to investigate the research questions. Subsequently, both employed methods are specified. Firstly, the survey approach will be put forward including sample selection, the development of the survey instrument, and the quantitative data analysis. Secondly, details regarding the interview procedure will be provided. This includes the selection of participants, the preparation of the interviews, and the approach for the analysis of the qualitative data.

3.2 Research Philosophy

In this section the philosophical stance that this research is based on will be discussed. Research within management science can be associated with different philosophical positions. Historically, scholars in the domain of management science including inter alia management science, operational research and information systems have taken on an empiricist as well as a conventionalist perspective (Mingers 1992, 2000). According to the former reality can only be observed or experienced. This philosophy attempts to derive causal relationships of collected data by mathematical modelling (Mingers 2006). In particular, American journals used to be more positivist with articles predominantly based on statistical analysis. Orlikowski and Baroudi (1991) analysed information systems literature published between 1983 and 1988 in four leading American journals. The authors found that the positivist perspective prevailed in the 155 investigated publications. Likewise, Walsham (1995) identified a dominance of positivism within American journals while observing an increasing receptivity for other philosophical paradigms like interpretivism. A more recent literature review of journal articles within the field of SCM confirms the prevalence of positivism (Burgess et al. 2006). Having realised that companies are social entities the interpretivist perspective gained relevance within management science though (Jackson 1993). The paradigm accentuates the dependence of science on individual perception and judgement (Mingers 2000). Thus, a growing number of research papers are based on interpretivist foundations (Winter 2006; Yeo 2002). Another philosophical paradigm that recently evolved in management science is critical realism. The value of critical realism for management science is emphasised by Mingers (2000, 2006). Critical realism distinguishes between the Real, the Actual and the Empirical. The former relates to those structures and mechanisms representing reality. According to the critical realist perspective the interaction of such structures leads to events, the Actual. Finally, only the observed or experienced events constitute the Empirical. Thereby, critical realists recognise that human knowledge is constrained by perception and experience while acknowledging an observer-independent reality (Mingers 2006).

This research firstly intends to generate a comprehensive view on current APS implementation of companies in the food industry. After having examined the status quo of APS adoption in the food industry, antecedents of APS implementation are investigated and an adapted TAM is developed. Lastly, possibilities how to improve implementation projects are explored. Technology such as ERP systems or SCP software are attributed “emergent properties” (Dobson 2001, p. 208). Especially with respect to research in the domain of information systems, scholars recommend taking also the interplay between actors and technology into account. Therefore, Dobson (2001) prefers a critical realist perspective over a closed experimental design as favoured by positivists. Besides the closed research setting the positivist approach is strongly limited by the fact that the paradigm considers only observed and experienced events. Thereby, the philosophical paradigm inevitably takes certain aspects of reality not into account. Complex interactions and underlying mechanisms are not identified. The positivist view rather indicates patterns and can be used for descriptions instead of explanations of specific organisational practices as argued by several scholars (Dobson 2001; Mingers 2006, 2000). The research by Gottschalk

(1999) greatly reveals the constraints of statistical modelling as commonly applied by positivists to analyse certain relationships. The author investigated the relationships between content characteristics of IT strategy and implementation of IT projects by means of multiple regression analysis. Against the author's expectations the theorised relationships were mainly identified as insignificant. Consequently, complex relationships that could not be reflected in the statistical model were assumed by the scholar. Furthermore, the significance of independent variables was expected to vary due to contingencies. Political and strategic issues within organisations could also not be modelled. This research is not supposed to make only descriptions about the implementation of APS, but also aims to examine why certain companies in the food industry decide to use SCP software and others not. Another objective of this research is to recognise mechanisms how the implementation of SCP software can be facilitated.

Positivism also neglects the idea that experiences and observations could be biased by human perception. Consequently, the validity of information gathered, e.g. by interviews with SC or IT managers, is taken for granted according to the positivist view (Mingers 2000). Managers may even not be willing to give statements that mirror reality of organisational processes. Respondents might fear personal consequences or may not want to disclose confidential information towards competitors. Therefore, interviewees could be inclined to give misleading answers that do not match reality of SCP practices in their companies. Besides that, managers might also be not knowledgeable enough to give a comprehensive overview of SCP practices. At least the latter may be bypassed by identifying the right contact person in an organisation though.

In contrast to the positivist paradigm, the interpretivist perspective acknowledges the subjectivity of answers that might be encountered during interviews. Thus, individual perceptions and observations are accepted as reality. This view recognises the individuality of people and processes in companies (Mingers 2000). The emphasis on the uniqueness of organisations, their processes and challenges in relation to APS adoption seems adequate. Nonetheless, certain aspects regarding SCP practices may be considered as objective. For example, an ice cream manufacturer needs to provide the optimal amount of ice cream to retailers. Therefore, consumer demand is forecasted and the production is adjusted to the actual demand without creating too much spoilage. In addition, the company needs to ensure the availability of resources including raw materials but also human resources to produce the ice cream. In this case SCP practices can support the ice cream manufacturer to provide the right type of ice cream at the right time and place to their customers. Planning issues such as the trade-off between out-of-stock situations meaning less revenue and more spoilage exist not only for the dairy, but also for the meat and brewing industry, and other food sectors. In spite of differing individuals and organisational habits the underlying approaches for such exemplary planning challenges are independent of individual perceptions. Also, the accompanied adoption of SCP software as response to these organisational complexities can be expected to be similar across the food industry. The differentiation between epistemic relativism and judgmental relativism is a characteristic of critical realism that is strongly supported. Even though people have different views about organisational practices, researchers are able to rationally decide which statements best mirror reality (Mingers 2000). Therefore, the paradigm of critical realism is considered as a good compromise. The philosophical stance "maintains reality whilst recognising the inherent meaningfulness of social interaction" as depicted by Mingers (2000, p. 1267).

Positivism as well as interpretivism are viewed as constrained based on the argument of "epistemic fallacy" as put forward by Bhaskar (2013). The positivist stance only acknowledges the experienced and observed events as real while the interpretivists are convinced of the non-existence of an independent reality and assume everything to be relative depending on subjective perceptions of reality (Bhaskar 2013; Mingers 2006). The philosophical paradigm of critical realism resembling systems thinking depicts the complexity of organisational operations (Mingers 2011, 2015; Holweg and Pil 2008). Strategic planning and decision-making in companies is known to be complex and involves many interacting issues and stakeholders (Pidd 2004; Houchin and MacLean 2005; Aligica 2005). SCP itself can be defined as the coordination of demand-facing and supply-facing activities within an organisation, and is considered as a process to accommodate the complexity of supply chains (Jonsson and Holmström 2016). APS have been developed to support this. The philosophical stance of critical realism that recognises the complexity of organisational processes is viewed as most appropriate to capture the reality of technology adoption behaviour of companies regarding APS.

Overall, critical realism is considered as a reasonable philosophical stance for this research project. The philosophical paradigm recognises human perceptions and acknowledges an observer-independent reality (Mingers 2006). The positivist view reduces reality to observed and experienced events while the interpretivists do not believe in an independent reality and assume everything to be relative depending on subjective perceptions of reality (Bhaskar 2013; Mingers 2006). The critical realist perspective is particularly valuable for the analysis of SCP practices including the adoption of SCP software. Critical realism considers ideas of systems thinking which fosters the understanding of complex interactions leading to decisions in organisations.

The critical realist perspective accepts the existence of various entities and encourages a multimethodological approach to enable a comprehensive view of the material, personal and social world (Mingers 2006). Therefore, a mixed methods research design is employed in this research. Insights about the level of APS adoption as well as context factors are gained through a survey among firms in the food industry. Subsequently, semi-structured interviews with experts in the domain of SCP are used to interpret the results and generate more in-depth knowledge. By means of a combination of research methods it is more likely to capture the underlying structures and mechanisms regarding the adoption of APS (the Real) (Mingers 2006). The methods used to investigate the research questions will be specified in later sections of this chapter.

Finally, the critical realist perspective will contribute to the previously mentioned research objectives and will facilitate practical advice for the implementation of SCP software in the food industry. A better understanding of the underlying mechanisms of APS adoption including requirements, drivers and barriers to APS implementation will enable companies to make better use of this technology to efficiently and effectively plan their supply chain activities and thereby enhance overall company performance.

3.3 Research Design

This section provides an overview of the research design employed for this study. This research comprised four phases. The research design is also summarised in Figure 3.1.

In the first phase of this research a systematic literature review was conducted. In this phase the literature on SCND, S&OP, IP and PP&S in the food industry was analysed. Likewise, the current state of research on APS implementation and technology adoption in relation to APS was reviewed. The literature review revealed that multiple models for SCP practices have been developed. Empirical literature on APS implementation is sparse though. Similarly, research on technology adoption regarding APS is limited.

A mixed methods sequential explanatory design covered the second and the third phase of this research. In the second phase a survey among firms in the food industry was conducted. The survey instrument was established in cooperation with the supervisors and experienced consultants in the domain of SCP based on the outcome of the literature review. Pilot studies were conducted with six consultants. The main objective of the survey was to create an accurate overview of APS implementation in the food industry. This corresponds to the lack of empirical literature regarding the implementation of APS to support SCP practices. In addition, the survey was used to gather insights on the PU of software modules for SCP and barriers to implementation. Survey respondents included IT and SCM professionals of food companies. The survey generated 34 responses. Subsequently, the quantitative data were analysed. Different statistical tests were employed to explore differences between the organisational context and the use of SCP software as well as the PU of APS modules.

In the third research phase semi-structured interviews were conducted with practitioners of food producers, software vendors, and consultants. The interview guide was developed based on the outcome of the survey after iterative discussions with the supervisors. The objective of this research phase was to gain more in-depth understanding of APS implementation in the food industry. In particular, data on drivers and barriers to APS adoption as well as system and organisational requirements for APS implementation were gathered. In addition, practical advice how to facilitate software implementation projects was queried. The triangulation of data provided different perspectives on APS implementation of the respective groups of experts. The qualitative data from the interviews were analysed with academic rigour. This was achieved by following a clear procedure for thematic analysis suggested by Creswell (2013). Lastly, the results were summarised and interpreted within the themes that emerged from the data analysis. The mixed methods research design comprising the second and third phase of this study is specified in the following sections. In particular, the individual approaches of the two selected methods, the survey and the semi-structured interviews, are outlined.

In the last phase of this research the results from the mixed methods research were analysed jointly. The survey outcome was discussed together with the interview results. In addition, the research findings were used to develop the propositions regarding antecedents of APS adoption further. An adapted TAM was introduced that provides explanations for APS implementation by companies based on the gathered data.

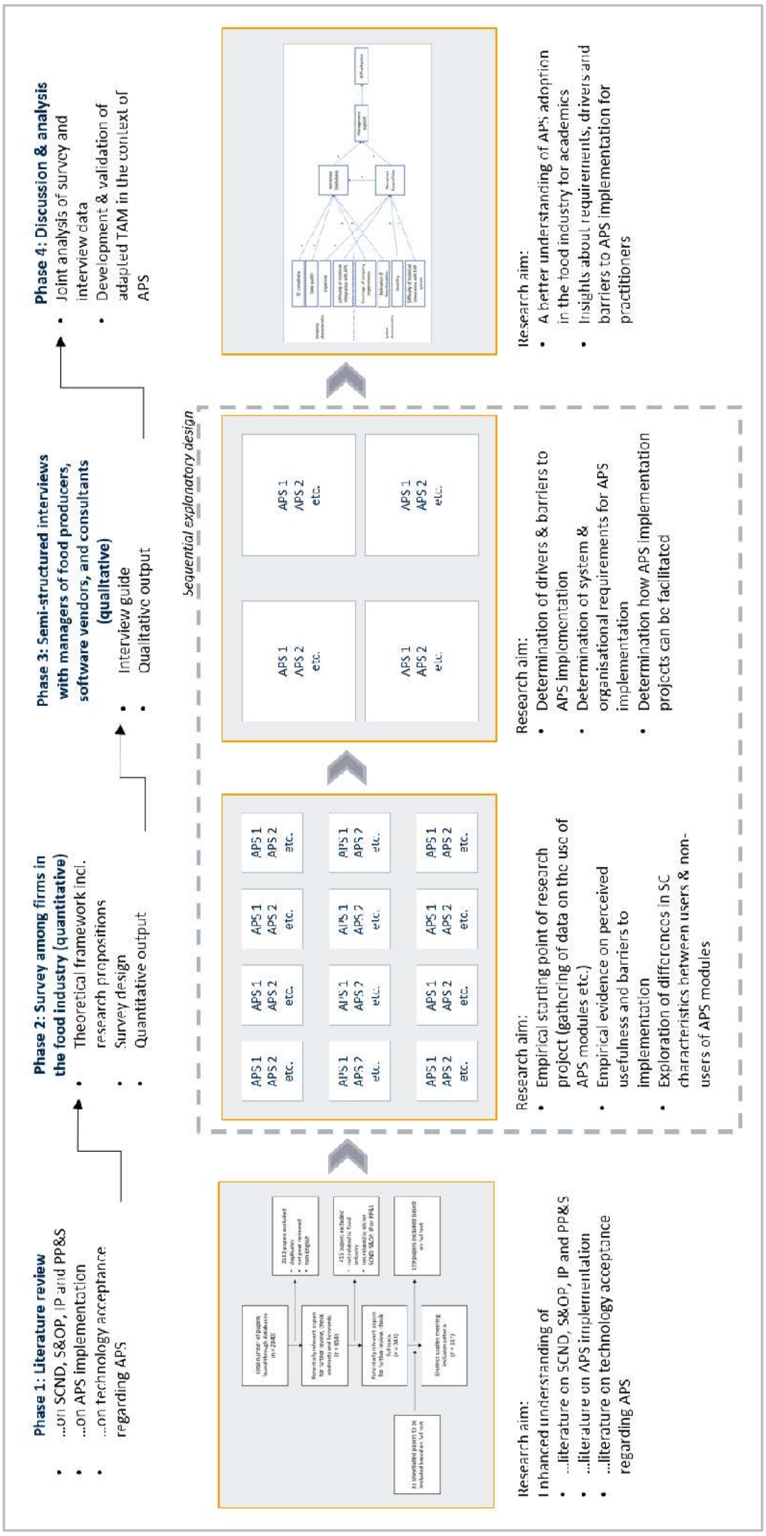

Figure 3.1: Research design (based on author's own research).

3.4 Research Methods

After having defined the philosophical stance and the research design, the research methods employed to investigate the research questions will be explained in the following sections. For this study mixed methods research is used to answer the research questions and thereby to contribute to a better understanding of APS adoption in the food industry. Mixed methods research incorporates the use of quantitative and qualitative research methods. This includes the collection of quantitative (closed-ended) and qualitative (open-ended) data and the rigorous analysis and interpretation of such (Johnson et al. 2007). Mixed methods research draws on the strengths of quantitative and qualitative methods and limits the weaknesses of single quantitative and qualitative research studies. Quantitative methods can be useful to gather large-scale data efficiently. In contrast, data gathered by means of quantitative methods can be insufficient to reveal complex and unstructured interactions within organisations. Important factors might be missed by solely relying on numerical data through using quantitative methods (Kiessling and Harvey 2005; Johnson and Onwuegbuzie 2004). Qualitative methods provide useful means to better understand the reasons behind certain behaviour in organisations and can add meaning to the data gathered by quantitative methods. Therefore, the combination of quantitative and qualitative methods is encouraged by different authors (Kiessling and Harvey 2005; Cavaye 1996; Johnson and Onwuegbuzie 2004; Shibly et al. 2022). Mixed methods research is considered as useful to generate a more complete understanding of the investigated topics for theory and practice. In addition, this research paradigm can answer different research questions as mixed methods research is not restricted to one single quantitative or qualitative research method (Johnson and Onwuegbuzie 2004).

There are three main types of mixed methods research designs: Convergent mixed methods design, explanatory sequential mixed methods design, and exploratory mixed methods design (Creswell and Creswell 2018). In a convergent design quantitative data and qualitative data are collected and analysed in one phase. The key rationale behind this approach is that quantitative and qualitative data convey different information. For instance, different information regarding a certain variable can be gathered by means of quantitative and qualitative research methods. In a next step the results are merged and similarities as well as differences revealed in the two types of data are discussed and interpreted. An explanatory sequential design incorporates the collection of quantitative and qualitative data in two phases. In the first phase quantitative data is collected. After that the data is analysed. The analysis of the quantitative data then provides the basis for the qualitative research method in a second phase. Thus, questions asked in the second phase may be derived from the analysis of the quantitative data. The idea of this mixed methods design is that the qualitative data help to explain the quantitative results and provide more in-depth information regarding a certain topic. In the exploratory design qualitative data is collected and analysed in the first phase. In the second phase a certain feature (e.g. a new website, a new variable) is identified. In the third phase this new feature is tested by means of a quantitative research method. Afterwards it is analysed if the new feature has led to improvements (Creswell and Creswell 2018).

The intent of this research is to generate a better understanding of APS adoption by companies. For this purpose, this mixed methods research followed an inductive approach. An explanatory sequential design was selected comprising a survey and interviews. In contrast to other mixed methods research designs, the explanatory sequential design allowed to obtain an overview of APS implementation in the first phase. The survey outcome could serve as foundation for the subsequent interviews where more in-depth qualitative data on APS adoptions could be gathered. Based on that, the initial propositions from Chapter 2 regarding different factors affecting APS adoption could be refined. The research activities are also depicted in Figure 3.1. Both research methods complement each other and provide stronger evidence to generate valuable insights on APS implementation in the food industry (Johnson and Onwuegbuzie 2004). Quantitative data were collected by means of the survey in order to gain an overview of APS implementation in the food industry. A survey offers different benefits for this research. The survey allows to easily gather data regarding APS implementation from multiple companies across diverse geographic regions.

Thereby, a survey can create a ‘bigger picture’ on APS implementation in the food industry as opposed to the existing case studies that only reveal APS adoptions of a few companies. In addition, a survey provides precise, quantitative data that are largely independent of the researcher. In contrast, survey data solely indicate numbers, provide limited context information and can thus be considered as rather abstract (Johnson and Onwuegbuzie 2004). The interviews as qualitative method can add meaning to the quantitative data and are useful to generate more in-depth knowledge on APS implementation. For instance, drivers and barriers to APS adoption can be further investigated in this part of the research. Organisational settings and mechanisms are different across companies in the food industry. Interviews are useful to capture individual perspectives of managers in the field of SCP regarding the implementation of APS including context factors. Interview participants are enabled to share their experiences by this research method. The interviews can also be utilised to understand certain survey results better (O'Cathain et al. 2007). Overall, the selected explanatory sequential design consisting of a survey and interviews is considered as reasonable approach to obtain a thorough understanding of APS implementation in the food industry and to answer the research questions adequately.

The validity of the resulting data was ensured by different measures. For example, the validity of the survey data was targeted by means of a rigorous survey design including appropriate scales. Likewise, the validity of the research findings from the interviews was pursued by triangulation of data and validation of the resulting model through experts. The quality of the survey and interview data is discussed in later sections of this chapter. The quantitative and qualitative studies followed the ethical standards of the University of Strathclyde. For both methods ethical approval was obtained.

3.5 Survey

The quantitative part of the mixed methods research approach involves an online survey. An online survey allows to efficiently gather data from multiple companies and various geographic regions (Saunders et al. 2019). The purpose of this method in the first phase of the explanatory sequential design is rather descriptive. The survey is supposed to provide an overview regarding the level of APS implementation in the food industry. In addition, empirical evidence of the PU and barriers to implementation is gathered. In the following sections the approaches for data collection and survey preparation will be explained. Lastly, the data quality of the online survey and the applied methods for data analysis will be discussed.

3.5.1 Sample Selection

In this section the sample selection for the online survey will be outlined. A list of 1,023 managers of food companies located in Germany, Austria, Switzerland and Italy was used as a sampling frame for the survey. The study focused on German food producers. Companies from other countries in the DACH region (Germany, Austria and Switzerland) and Italy were included in the sampling frame for the survey to ensure sufficient responses. Since the employment of software tools to support SCP practices is expected to be similar across these countries, this should not have an impact on the outcome of the study. The list including email addresses was gathered from a database of a German consultancy. Companies with revenue below EUR 20 million (mil.). were excluded from the sampling frame before. Smaller companies may not require software tools for SCP due to less complex organisational structures. The sample of participants was obtained from the sampling frame.

Volunteer sampling was chosen as sampling technique for the internet-based survey. The primary purpose of the first phase within the mixed methods research design was to gather an overview regarding the use of APS modules in the food industry. The managers in the sampling frame had superior roles in either IT or SCM departments. The latter group of managers could hold diverse positions within SCP, production, logistics and warehouse management. All professionals were expected to have comprehensive knowledge regarding the use of APS modules supporting SCM within their companies. Therefore, all managers of the food companies in the sampling frame were invited to voluntarily participate in the online survey.

The initial mailing and one follow-up generated 31 responses. A large part of five survey responses was not filled. Due to the missing values the number of responses was reduced to 26. Thus, the effective response rate of 2.5% was relatively low compared to other surveys in the domain of SCM (Wagner and Bode 2014; Devaraj et al. 2007). Hence, individual consultants were asked to complete the survey in order to supplement the number of responses. Before, the consultants were taught to complete the survey from the perspective of their client firm. Only consultants with sufficient expertise regarding the software tools used by their customer were contacted. The consultants were only acting as management consultants and were not involved as system integrators in a software implementation project. Thereby, it was ensured that the additional eight responses are accurate and not biased. The final sample contained 34 completed survey responses. Further information regarding the final sample of the online survey is provided in Chapter 4.

3.5.2 Development of the Survey

Standard techniques were followed for the development of the survey (Dillman 2011). The survey was established in cooperation with the supervisors and experienced consultants in the domain of SCP. After iterative discussions a final draft of the survey was developed and pretested by conducting pilot studies with six consultants. In particular, a proper understanding of the questions and the ease of use of the questionnaire was considered at this stage in order to maintain the managers' interest and to prevent dropouts. Subsequently, few modifications were incorporated. In the following section the final survey instrument will be outlined.

At the beginning of the survey an introduction to the study's objectives was included. The initial questions were general questions related to the company (e.g. food sector, company size) and the role of the survey participants. To capture the use of APS modules, managers were asked to indicate the use of software tools in different areas of application successively. Descriptions of the respective modules were attached to ensure that survey respondents have a proper understanding of the scope of application of APS modules. Survey participants rated the utilisation of software modules based on a four-point Likert-scale (1: “In use”, 2: “Implementation planned within next 2 years”, 3: “Implementation planned within next 2 to 5 years”, 4: “No implementation planned”). If companies use or plan to implement a certain module, the name of the respective software was inquired.

The subsequent part of the questionnaire provided further insights regarding the use of software modules of four critical fields of application of SCP for food companies: SCND, S&OP, IP, and PP&S (Ahumada and Villalobos 2009; Trienekens et al. 2012; Bilgen and Günther 2010; Nagurney 2013). First of all, respondents were asked to specify how familiar they are with respect to these different software modules based on a 5-point Likert scale (1: “Extremely familiar”, 5: “Not familiar at all”). After that, managers were required to report on the functions of the four APS modules. Coverage of common software functions was assessed on a four-point Likert-scale (1: “Extensively covered”, 4: “Not covered at all”), whereas the benefit of the respective functions was queried on a five-point Likert-scale (1: ”Extremely useful”, 5: “Not useful at all”). The functions of APS modules were largely retrieved from existing literature (Lütke Entrup 2005). Further functionalities included in the employed software to support SCP could be indicated by the managers. Likewise, participants were asked in an open question to determine further functionalities that would be needed to effectively support their planning decisions. Moreover, implementation projects were evaluated by the managers based on a validated four-item measure from a study by Hong and Kim (2002) covering different dimensions of implementation success (cost, time, performance and benefits). Consultancy firms often take responsibility for model building, integration with the existing IT infrastructure and training of key users within APS implementation projects (Ivert and Jonsson 2011). The expertise of consultants was evaluated based on a three-item measure reflecting technological, industry, and change management know-how. Each of the knowledge dimensions was rated on a five-point Likert-scale. Participants could also indicate, if there were no consultants involved in the project or if they had no insight regarding the consultants' expertise.

If a specific module was not applied by a participating company, respondents were asked to assess barriers to software implementation on a five-point Likert-scale. Factors were selected based on prior research on BDA and ERP systems (Arunachalam et al. 2018; Momoh et al. 2010). Apart from the given variables respondents had the opportunity to reveal further barriers. Moreover, survey participants were supposed to estimate the potential benefit of APS functions for their company's supply chain assuming they were using the software.

The survey incorporated a validated measure of supply chain complexity (Jonsson and Ivert 2015; Bozarth et al. 2009). Jonsson and Ivert (2015) measured the construct based on four dimensions encompassing demand uncertainty, production uncertainty, supply uncertainty and detail complexity. For this study the latter scale of detail complexity was adapted and measured by the amount of stock keeping units (SKUs) in the product portfolio. Production uncertainty and supply uncertainty were measured by two items each. In addition, average shelf life of the produced food items was queried to accommodate the perishability of food which is characteristic for the industry. Ordinal scales were used to inquire the different dimensions of complexity. The survey can be found in Appendix 1.

3.5.3 Quality of the Survey Data

The quality of the survey data depends to a great extent on the validity and reliability of the survey instrument. A measure is valid when it reflects what it is supposed to measure, whereas a reliable measure gathers data consistently (Saunders et al. 2019; Babbie 2016).

Scholars refer to different types of evidence for valid measures depending on the research questions. The previously outlined survey instrument can be considered as valid measure due to its face validity and content validity. Face validity describes to what extent a measure appears to be reasonable (Babbie 2016). The survey included several single-item measures. This is also due to the rather descriptive purpose of the online survey. Most responses were based on five-point Likert scales. According to Bergkvist and Rossiter (2007) single-item measures are acceptable, if the variable is concrete and unidimensional. The use of specific software modules can be considered as an example for the latter. Face validity of the survey instrument was confirmed in the pilot tests. Content validity constitutes the degree to which different types of a concept are covered by a measure (Babbie 2016). A validated measure for implementation success was thus included in the survey (Hong and Kim 2002). The success of an APS implementation was measured by the perceived deviation of expected costs, time, system performance, and benefits. Furthermore, a validated measure for supply chain complexity was selected from previous research (Jonsson and Ivert 2015; Bozarth et al. 2009). Average shelf life of products was included in the measure as further dimension of supply chain complexity to incorporate the perishability of food products. Therefore, the measures in the survey can be attributed content validity. The survey instrument is regarded as valid measure based on the results of the pilot study and the largely unidimensional variables (e.g. the use of APS modules) that were queried.

Likewise, the reliability of the measure was ensured. An introduction to the study’s objectives was included at the beginning of the survey. In addition, survey questions were worded clearly and unambiguously to avoid any possible misunderstanding. The outcome of the pilot study revealed that the questions were well understood and interpreted consistently by the survey respondents. No inconsistencies in the responses could be determined. The reliability of the data can also be reduced by distortions in survey responses (Saunders et al. 2019). Survey participants could provide uninformed responses due to a lack of knowledge or experience (Saunders et al. 2019). The participants of this online survey were considered as highly knowledgeable with respect to the SCP processes within their company though. Only managers with superior roles in either IT or SCM departments were asked to participate in the online survey. Managers could further be inclined to fill out the survey in such a way that is viewed favourably by others. Hence, higher maturity levels of SCP practices could be indicated (Yin 2017). Therefore, participants were assured that their individual responses would be kept confidential. Additionally, surveyed managers were given the opportunity to receive a feedback report regarding the survey outcome. A feedback report may reduce distortions due to such response biases. Managers might be interested in obtaining an accurate picture of current APS implementation in their industry and thus give more precise answers. The opportunity to receive an email report should also contribute to increased motivation to participate in the survey and prevent dropouts. Thereby, the likelihood of distorted survey responses was reduced. The survey instrument can thus also be considered as reliable measure.

This study is rather exploratory. The findings of the survey may not be generalised due to the low response rate. Reasons for the low response rate could be a lack of understanding or the length of the survey. Small samples are frequently used in SCM research. Recommendations for survey-based studies that rely on small samples were followed to enhance the validity and reliability of research findings (Beuckelaer and Wagner 2012). Overall, the quality of the gathered survey data was ensured based on the careful design of the survey instrument along with the rigorous sample selection and pilot testing. In the next section, it is put forward how the quantitative survey data was analysed.

3.5.4 Analysis of the Survey Data

After the survey was conducted, the data was analysed. A core objective of the survey was to create an overview of APS implementation in the food industry. Moreover, the survey aimed to gather insights on the PU of software modules for SCP and barriers to APS adoption. The relevant variables were queried as part of the survey. The survey results were analysed and summarised via descriptive statistics.

In addition, the survey data was utilised to examine potential differences between companies using and not using APS regarding supply chain complexity and company size. Similarly, differences regarding the PU of APS modules for companies with different levels of supply chain complexity and company size were investigated. Lastly, the PU of APS modules was compared between food producers using and not using the respective software. The comparison of means can be useful to check, if two or more samples differ in their central tendencies. Various tests for the comparison of means of two groups exist (see Table 3.1). Different questions need to be addressed to select the most appropriate statistical test. Firstly, the two samples can be independent or dependent. The latter is the case if the same sample is studied at different points in time. The means of two dependent samples can be compared with a paired t-test. This statistical test assumes that the dependent variable is normally distributed and scaled metrically (Saunders et al. 2019). The non-parametric equivalent is the sign test which can be used, if the dependent variable is either not metrically scaled or not normally distributed (Veaux et al. 2021). The means of two independent samples can be compared by using an independent samples t-test. The dependent variable should be measured metrically and the variable should be normally distributed. If the requirements are not fulfilled, a non-parametric test, the Mann-Whitney U test, can be used (Dancey and Reidy 2017).

For this study, the independent samples t-test was used to compare the means of the different groups. The survey responses were considered as independent from each other. The online survey could be only filled out once per respondent. The dependent variables were measured on quasi-metric Likert scales. According to the central limit theorem the distribution of a sample variable approximates normal distribution as the sample size increases. The sample for the independent samples t-test should not be lower than 30 (Saunders et al. 2019). In most cases this condition was fulfilled. Moreover, the t-test requires equal variances. Levene's test was applied to check the equality of variances. If the null hypothesis of equal variances was rejected, the Welch test was applied. The Mann-Whitney U test was conducted additionally to compare the respective groups due to the small sample size. The tests were one-tailed because it was assumed that supply chains of companies using APS modules would be attributed higher complexity. Likewise, companies with higher supply chain complexity were expected to indicate a higher usefulness of APS modules as outlined in Chapter 2. Effect sizes were reported corresponding to Cohen (2013). SPSS was used for the analysis of the quantitative survey data. Overall, the data was analysed with academic rigour in spite of the small sample size as recommended in previous literature (Beuckelaer and Wagner 2012).

Table 3.1: Statistical tests to compare means of two groups (based on Saunders et al. (2019) and Veaux et al. (2021)).

Analysis	**Parametric test**	**Non-parametric test**
Comparison of two independent groups	Independent samples t-test	Mann-Whitney U test
Comparison of two related groups	Paired samples t-test	Sign test

3.6 Semi-structured Interviews

In the second phase of the explanatory sequential design interviews were conducted. The approach for the interviews will be specified in this section. It is usually differentiated between three types of interviews: Unstructured interviews, semi-structured interviews, and structured interviews (Saunders et al. 2019; Bell et al. 2022). Unstructured interviews are rather informal. There is no predetermined questionnaire or structure for the interview. In this type of interview certain topics are discussed in an emergent and exploratory manner. Questions are asked by the interviewer depending on the course of conversation. Semi-structured interviews follow a predetermined structure. Prior to the interview an interview guide covering a few themes with related questions is defined. Based on the interview guide the themes are investigated systematically with each interview participant. Depending on the interview some questions are discussed in more detail. Structured interviews are conducted by means of complete questionnaires. The questionnaire comprises standardised questions. In structured interviews identical questions are asked by the interviewer with the same intonation. This type of interview is usually conducted to gather quantifiable data (Saunders et al. 2019).

For this research semi-structured interviews were selected as interview method. This interview type is considered as useful method in mixed methods research to explore and validate themes that have emerged from a survey (Teddlie and Tashakkori 2009). The semi-structured interviews are supposed to add meaning to the survey results and to gather in-depth data regarding APS implementation in the food industry. Based on the survey outcome specific topics can be investigated in more detail. Similarly, this interview method is viewed as practical means to understand the motives why certain food companies decide for or against the implementation of APS modules (Saunders et al. 2019). In addition, the limitations of unstructured and structured interviews can be overcome. Unstructured interviews provide comprehensive information regarding selected topics, whereas the analysis of the interview data is more complex and the views of different interviewees can hardly be compared due to the lack of structure. In contrast, the data analysis of structured interviews is less complex. The depth of the data is limited though and insights from this type of interview are rather generic. In structured interviews the interviewer has no opportunity to ask for additional explanation of the provided responses (Silverman 2021). Semi-structured interviews enable the comparison of interview results between different interview participants due to the given structure of the interviews. For instance, the perspectives of different experts regarding drivers and barriers to APS adoption can be analysed by means of semi-structured interviews accordingly. Semi-structured interviews also allow flexibility since the interviewer can ask for further insights of the provided information (Bell et al. 2022). Thereby, more depth of the data can be generated. Likewise, background information and contextual data regarding APS implementation in the food industry can be gathered (Saunders et al. 2019).

In the next sections the selection of interview participants, and the way how the semi-structured interviews were prepared and conducted will be specified.

Moreover, the quality of the interview data is discussed and the approach for the analysis of the qualitative interview data will be put forward.

3.6.1 Selection of Participants

In this section the type of sampling method for the semi-structured interviews will be discussed. Two types of sampling methods are typically differentiated. These are probability and non-probability sampling techniques. Probability sampling methods usually refer to mechanisms where the sample of a population is randomly selected. Non-probability sampling refers to techniques where the sample is not randomly selected (Saunders et al. 2019; Babbie 2016).

For this research a non-probability sampling method was selected to ensure that only experts in the field of SCP were interviewed. Different non-probability sampling techniques exist. Quota sampling is a technique whereby the sample is selected based on predefined variables. The rationale behind this method is that the final sample should have the same variability in terms of the specified characteristics as the studied population. Purposive sampling is another method where the sample is selected based on the judgement of the researcher. Certain participants may be considered as more useful for the study than others. Another non-probability sampling method is volunteer sampling. By means of this approach participants volunteer for the research instead of being selected. Haphazard sampling is used when the units of the sample are chosen without consideration of the research objectives. An example of this method is the selection of participants solely based on availability (Saunders et al. 2019; Babbie 2016).

For this study purposive sampling was chosen as non-probability sampling technique. The primary purpose of the second phase within the mixed methods research design was to gather more in-depth data regarding the implementation of APS modules in the food industry. Managers of food companies, software vendors and consultants were considered as particularly informative. Managers of food producers could provide insights regarding the adoption of software for SCP. The views of food companies were complemented by the perspectives of software vendors and management consultants. Only managers with many years of experience in the domain of SCP within the food industry were approached for the interviews. More details regarding the interview participants are presented in Chapter 5. Thereby, a holistic picture of APS implementation in the food industry could be generated by means of purposive sampling. The triangulation of data should contribute to a better and broader understanding on APS adoption. In addition, the validity of the generated data should be increased (Saunders et al. 2019).

3.6.2 Preparation of Interviews

In this section it is put forward how the interviews were prepared. Saunders et al. (2019) advised three measures to prepare for interviews and to obtain the required credibility among interview participants. These include the gathering of useful information, the provision of interview themes to the interview participants, and the selection of a suitable interview location. In the following it is described how these recommendations were followed.

Firstly, it was ensured to obtain sufficient contextual information about the organisations of the interviewed experts. For this purpose, primarily the websites of the individual companies were examined prior to the interviews. Background information such as financial data, company size, and the product portfolio of the companies were gathered to prepare for the interviews with the managers of the food producers. Moreover, press releases could give hints regarding recent developments in the companies. Internet research revealed also useful information about the interviewed software vendors to facilitate the interviews. Besides the size of the software companies, the offering of APS modules and the key industries of their customers were investigated. Similarly, the website of the consulting firm of the interviewed consultants provided insights about the size of the consultancy, consulting services, and industries of their clients.

Secondly, an interview guide for the semi-structured interviews was developed based on the systematic literature review and the survey outcome of this study. The purpose of the interviews was to investigate drivers and barriers to APS adoption, requirements for APS implementation, and to explore how APS implementation projects can be facilitated. The developed interview guide comprised questions related to these themes in comprehensible language and in a logical order as advised by Saunders et al. (2019). The interviews started with an introduction. The first set of questions addressed systemic as well as organisational requirements for APS implementation. After that, a few explorative questions were asked to better understand the ease of use of APS. Subsequently, drivers and barriers to APS implementation were queried in a set of open questions. In the final section of the interviews it was asked how companies could capitalise the most on APS and how the implementation of these software tools can be facilitated. The focus of the interviews slightly differed between the managers of the food companies and the external experts. The interviews with the former primarily served to understand the perspectives of food producers regarding SCP software in their individual contexts. The conversations were more targeted towards drivers and barriers to APS adoption as well as potential requirements for APS implementation. Opportunities for improvement of software projects were rather neglected in these talks. The interviews with software vendors and consultants provided the views from external experts regarding the different aspects of APS implementation. The interview guide was discussed several times with the supervisors and a dry run was conducted to ensure a natural flow of conversation. The interview guide for the managers of food companies and the external experts can be found in Appendix 2. The interviewees were invited via mail to participate in the interviews. A participant information sheet was attached to the invitations. The managers were thus informed about major themes and the purpose of the research. The participants could thereby also prepare for the interviews and possibly even provide additional useful material in the interviews. The latter was the case in a few interviews. Likewise, the anonymity of data was guaranteed in the participant information sheet to reduce potential concerns of the interviewees regarding confidential treatment of the provided information.

Thirdly, the interviews were conducted via a video conferencing tool. Video conferencing had several advantages for this study as also confirmed in the literature (Saunders et al. 2019). Interview participants could stay in their familiar and safe environments. Face-to-face interviews might have led to anxieties among the interviewees as the interviews were conducted in times of the COVID-19 pandemic. Moreover, video conferencing enabled to interact visually at low cost although interviewees were geographically dispersed across countries. Lastly, the sharing of material and instant messaging was possible via the video conferencing software.

3.6.3 Conducting the Interviews

In this section it is explained how the interviews were executed. The conduct of the interviews impacts the reliability and validity of the gathered data. The guidelines put forward by Saunders et al. (2019) were followed accordingly.

The start of an interview is particularly significant to gain the confidence of the interviewees (Saunders et al. 2019). Each of the interviews was started by expressing the gratitude for the participation in the interview. After that, the interviewer introduced himself and the purpose behind the research including the interviews was iterated. Likewise, the anonymity of the interview data was emphasised as already stated in the participant information sheet. Subsequently the interview participants were assured that it was acceptable, if the interviewees were not willing or not able to answer certain questions. Moreover, the opportunity to receive a summary of the research results was indicated. The participants were also invited to ask any remaining questions. Lastly, the interviewees were asked to introduce themselves.

The questions in the interviews were articulated clearly with a neutral voice to avoid any interviewer bias. Most of the questions asked were open questions. Additionally, probing questions were partly used to explore specific topics more in-depth or to ask for more explanation of certain answers by the interviewees. Similarly, the interviewer tried to show interest through the voice, and at the same time maintained neutral behaviour to not indicate any personal judgement regarding the participants' responses. Sometimes answers were shortly summarised by the interviewer to ensure a correct understanding of the provided information. In the course of the whole interview the interviewer tried to be respectful, listen well, and stay within the specified time (Creswell 2013; Saunders et al. 2019).

Overall, the interviews lasted between 30 and 70 minutes. Most interviews were conducted in German and some of them in English language. The full interview was documented via notes by the interviewer. The completeness of the notes was checked immediately after each interview to avoid any loss of information. The notes were carefully translated into English language afterwards to not change the meaning in the original language. It was decided to not make use of audio-recording because of potential detrimental effects. As a consequence participants may have been inhibited to give certain answers or could have refused participation in an interview (Saunders et al. 2019). In the next section the quality of the interview data will be discussed.

3.6.4 Quality of the Interview Data

Different data quality issues need to be considered when semi-structured interviews are conducted. These are associated with reliability, different forms of bias, cultural differences, generalisability, and validity of the data (Saunders et al. 2019). In the following section the measures to avoid data quality issues are explained.

Data is considered as reliable, if other scholars would yield the same data with the applied methods. The exact replication of findings in qualitative research is viewed as not realistic (Saunders et al. 2019). The research process including the choice of the research method, how the data was obtained and analysed is described in detail though. Thus, the reliability of the interview data was ensured.

Different biases can also reduce the value of the gathered interview data. Firstly, limited data quality can be caused by interviewer bias. This type of bias can be generated when the responses of interview participants are influenced by the way the questions are asked. This could be due to the intonation or non-verbal behaviour of the interviewer. Interviewer bias can also exist, if responses by interviewees are not interpreted correctly, or if the interviewer is not able to gain trust of the interview participants. Response bias can be caused by interviewees. This bias is present when interview participants are not willing to reveal their true opinion. Thereby, only limited insights can be gathered from the interviews and the data can be distorted. Another bias can be generated by the type of interviewees willing to participate in the interviews. Participation bias is caused, if, for example, only managers from a specific organisation are taking part in the interviews. This could similarly result in one-sided and distorted interview data (Saunders et al. 2019). The interviews were conducted in a way to minimise the likelihood of the mentioned biases. Interviews were articulated with a neutral voice. The responses of interview participants were captured without any personal judgement. Sometimes probing questions were used to get more explanation of certain answers. Likewise, answers were partially summarised by the interviewer to ensure the correct understanding of the provided information. Interviewees were informed about the research prior to the interviews via the participant information sheet. The purpose of the research and the confidential treatment of the interview data was reiterated at the beginning of each interview. Thereby, credibility among interview participants was gained. The probability of distorted interview data due to response bias was thus reduced. Participation bias could be eliminated by the purposive selection of participants. All interviewees were considered as informative for this research and could provide different perspectives on the implementation of APS in the food industry. The participant profiles are outlined in a later chapter.

The quality of interview data can also be reduced by cultural differences between the interviewer and the interviewee. Different cultural backgrounds could imply different assumptions about privacy or how independently opinions can be expressed. In addition, cultural differences can reduce the information provided by interviewees, and can lead to misunderstandings and biased interpretations of the collected data due to a language barrier (Court and Abbas 2013). In this study the interview data was not negatively affected by cultural differences. All interview participants were located in Europe and most interviews were conducted in native language. Interview notes were carefully translated to not change the meaning in the original language.

Generalisability is associated with the question, if the findings are also true in other settings (Saunders et al. 2019). This research is rather explorative. More research is needed for the generalisability of findings. The interviews were still planned with academic rigour. In particular, the triangulation of different perspectives of managers of food companies, software vendors and consultants could yield a holistic view on APS adoption in the food industry.

Valid data is generated, if correct meanings as intended by the interviewees are derived from the interview responses (Saunders et al. 2019). In this research interview participants were informed about major interview themes and the purpose of the research prior to the interviews. The interviewees could thus prepare for the interviews and possibly provide even more useful insights. In addition, knowledge about the organisations of the interviewed experts was gathered by the interviewer before the interviews to better understand the given information. Similarly, questions were asked in the interviews to clarify specific responses. This should have contributed to an improved interpretation of the interview data. The validity of data was further enhanced by the exploration of APS adoption from different perspectives.

Overall, the sample selection, the preparation of the interviews and the way how the interviews were conducted ensured that valuable data could be gathered. The likelihood of the previously mentioned concerns regarding the quality of interview data could equally be minimised. In the next section the approach to analyse the qualitative interview data is described.

3.6.5 Analysis of the Interview Data

After the interviews were conducted, the interview data had to be analysed and interpreted. Different approaches exist to analyse qualitative data (Creswell 2013; Yin 2016; Saunders et al. 2019). These are not exclusive for specific research purposes. The methods for the analysis of qualitative data can be differentiated based on their analytical focus. Some techniques are focused on specific themes, other forms of qualitative data analysis are targeted towards the analysis of certain actions. Further methods are focused on the use of language (Saunders et al. 2019). The objective of this research phase was to gain more in-depth understanding of APS implementation in the food industry. Thematic analysis was thus selected for the analysis of the qualitative interview data. This approach was considered as useful method to systematically analyse different aspects of APS adoption in the interview data. The technique can be flexibly employed in deductive as well as inductive research (Braun and Clarke 2006). The interview analysis in this research was based on the reviewed literature and the survey results. Likewise, new themes were explored in the interview data. Thematic analysis of qualitative data comprises different steps. The technique is not a linear procedure as different steps are reiterated (Creswell 2013; Saunders et al. 2019). In the next section it is described how the different steps for thematic analysis outlined by Creswell (2013) were followed.

The first step was to organise the data. Comprehensive notes were taken during the interviews. Subsequently, the interviews were transcribed and the data were prepared for analysis. There are different ways to transcribe the data. The interview output can be transcribed in full or only relevant parts (Gillham 2010). For this research the full interview data were transcribed to ensure that all relevant aspects were captured in the data set. Those interviews that were conducted in German were translated into English. Various programs exist to support the analysis of qualitative data. The programs can be associated with different advantages and disadvantages (Creswell 2013; Yin 2016). Yin (2016) put forward that analytic decisions would still have to be met by the individual researcher, even when specialised software is used.

For the scale of this research Word and Excel were considered as sufficient. In addition, uncertain accessibility and ease of use of other computer programs led to the use of Word and Excel. Both programs can support a large part of the analysis process (Hahn 2008).

The second step of the data analysis was to read iteratively through the data and to familiarise with the interview output. The latter was also supported by the previous transcription and translation of the interviews.

As a third step the data was coded. At this stage the data was described and classified into codes. The purpose of this step was to reduce the data. Only the significant data should be coded. Creswell (2013) advised to have not more than 25 to 30 codes. The codes should reflect the insights from the original data (Creswell 2013). In this research, data was firstly described by initial codes. These codes are close to the original interview data and can also be described as Level 1 codes (Hahn 2008). After reading through the codes several times the codes were assigned broader categories (Level 2 codes) (Yin 2016). The codes were established based on the literature review and the interview data as suggested by Creswell (2013). The codes are presented in Table 3.2. In this study 27 codes were defined. These include, amongst others, "expertise", "data quality", "management support" or "company size". The code "expertise", for example, comprises different initial codes such as "IT expertise", "SC expertise", "project management skills" or "data skills". There are different views in scientific literature whether to consider the frequency of codes or not (Elliott 2018). In this study, the number of times certain codes appeared was neglected as not all codes were considered as equally significant following Creswell (2013). After that, the codes were grouped into themes. Between five and seven themes should be established (Creswell 2013). In this study five themes were determined. These are "system requirements for APS adoption", "organisational requirements for APS adoption", "drivers for APS adoption", "barriers to APS adoption", and "implementation projects".

In the last stage of the data analysis the interview results were summarised and interpreted. Firstly, the views of the food companies on APS and the individual contexts were outlined. After that, the outcome from the interviews with the managers of the software vendors and the consultants were analysed within the defined themes. The previous steps were carried out in an iterative manner and throughout several months to ensure rigour in the data analysis (Yin 2016).

Table 3.2: Overview of themes and associated codes (based on author's own research).

Themes	**Codes**
System requirements for APS adoption	• Functionalities • Ease of use • Technical integration with ERP system • Data security • Customer support • References
Organisational requirements for APS adoption	• Data quality • Expertise • Management support • Company size • SCM processes • Technical integration with APS
Drivers for APS adoption	• Specific use cases • SC complexity • Review of SCM practices • Job attractiveness • Change of ERP system
Barriers to APS adoption	• Lack of business case • Lack of management support • Lack of human resources • Complexity of interfaces

	• Lack of data quality
Implementation projects	• Maintain management support • Ensure availability of resources • Ensure high data quality • Highlight process requirements • Develop strategic view for targeted software adoption

3.7 Chapter Summary

In this chapter the methodology and methods used for this research were put forward. This research is based on the philosophical paradigm of critical realism. Mixed methods research was determined as most appropriate research approach to answer the research questions. An explanatory sequential design consisting of a quantitative survey followed by qualitative interviews was selected for this research. A main objective of the online survey was to create an overview of APS implementation in the food industry. In addition, the survey was supposed to gather data on the PU of software modules for SCP and barriers to software implementation. Volunteer sampling was chosen as sampling technique for the survey. A database including food companies located in Germany, Austria, Switzerland and Italy was used as sampling frame. The survey was developed after iterative discussions with the supervisors and experienced professionals. Subsequently, the survey instrument was pretested in pilot studies. The survey results were primarily analysed and summarised by descriptive statistics. In addition, different statistical tests were applied to investigate potential differences between companies using and not using APS regarding supply chain complexity and company size. In the following research phase semi-structured interviews were conducted to gain a more in-depth understanding of APS implementation in the food industry. In particular, drivers and barriers to APS adoption as well as requirements for APS implementation were investigated. 15 interview participants were selected for the interviews via purposive sampling to ensure that only experts in the domain of SCP were interviewed.

Managers of food companies, software vendors and consultants were interviewed to triangulate different perspectives on APS adoption. The interviews were prepared and conducted with academic rigour to ensure the quality of the interview data. Lastly, the qualitative interview data was examined and summarised via thematic analysis. In the next two chapters the survey and interview results are provided. After that, the results of the mixed methods research are discussed and an adapted TAM for APS is presented.

4 Survey Results

4.1 Introduction

The quantitative part of the mixed methods research approach involved an online survey. The survey primarily served to answer the first research question. In this chapter the survey results are presented. In the first section an overview of the data sample is provided. After that the survey outcome is put forward. Firstly, the use of SCP software of the surveyed food producers is outlined. In addition, survey results concerning success of implementation projects, barriers to APS adoption and PU of software modules for SCP are presented. Subsequently, the survey results regarding specific software modules to support SCP are depicted. The survey outcome is summarised in the last section of this chapter.

4.2 Survey Data

The internet-based survey was conducted between August and November in 2020. A sample of 1,023 managers of food companies in Germany, Austria, Switzerland and Italy was contacted by means of the survey to get an overview of software usage for SCP practices within the food industry. Email addresses were obtained from a database of a German consultancy. The database contained only companies operating in the food industry. Only managers with superior roles in either IT or SCM departments were approached. The latter group of managers could hold diverse positions within SCP, production, logistics and warehouse management. All respondents were expected to have comprehensive knowledge regarding the use of APS modules supporting SCM within their companies. Only companies with revenue above EUR 20 mil. were selected. Smaller companies may not require software tools for SCP due to less complex organisational structures. Additionally, individual consultants were asked to complete the survey from the perspective of client firms to supplement the number of responses. It was ensured that the responses are accurate and not biased. Levene’s test for equality of variances was applied to identify potential response biases. The outcome showed no significant differences in the responses between the managers of the food companies and the surveyed consultants. The same test was conducted for early and late respondents within the survey. Again, no significant difference in response behaviour could be determined (see Appendix 3).

The final sample contained 34 completed questionnaires. Table 4.1 shows some company characteristics of the final sample. The survey yielded responses from a wide range of food sectors. The participating companies were mainly located in Germany (76%). The sample included many mid-sized organisations, but also larger companies with an annual revenue above EUR 1 billion (bil.). Overall, the final sample was representative for the whole population of food companies in Germany in terms of revenue (see Figure 4.1). Most of the respondents were either head of SCM, CEO or COO of their companies. So they can be expected to be well aware of SCP processes within their company and of potential associated software tools.

Table 4.1: Company characteristics of the final sample (based on author's own research).

Company characteristics	**Number of responses (% of all responses)**
Food sector:	
Meat & meat products	5 (15%)
Dairy	1 (3%)
Sweets & snacks	8 (24%)
Frozen food	2 (6%)
Baked goods	1 (3%)
Convenience products	2 (6%)
Alcoholic beverages	6 (18%)
Non-alcoholic beverages	4 (12%)
Miscellaneous	5 (15%)
Country:	
Austria	2 (6%)
Germany	25 (76%)
Italy	1 (3%)
Switzerland	5 (15%)

Size (employees):	
20 – 49	1 (3%)
50 – 99	1 (3%)
100 – 249	4 (12%)
250 – 499	7 (21%)
500 – 999	10 (29%)
More than 1,000	11 (32%)
Size (revenue in EUR mil.):	
20 – 49	4 (12%)
50 – 99	3 (9%)
100 – 249	7 (21%)
250 – 499	6 (18%)
500 – 999	6 (18%)
More than 1,000	7 (21%)

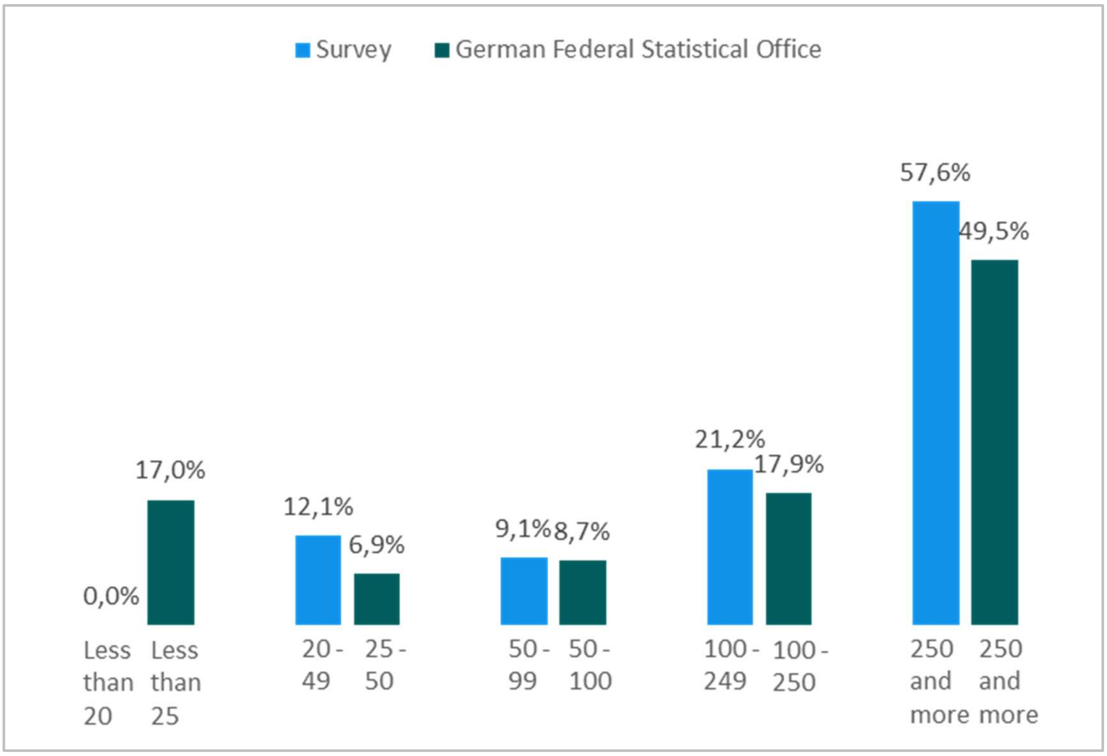

Figure 4.1: Distribution of revenue by different categories of revenue (in EUR mil.) in the final sample and in the German food industry in 2021 (adapted by the author from Statista (2023)).

4.3 Analysis and Results

The results of the survey revealed that the participating food companies used dedicated software tools for SCP only to a limited extent (see Figure 4.2). 42% used specialised software systems for PP&S. 38% of the surveyed companies utilised corresponding software solutions for IP and 36% supported the S&OP process with specific software. In addition, 4% stated that they would use dedicated software supporting strategic decisions (SCND), e.g. regarding number and location of production facilities. 36% of the participants indicated that the implementation of a software for the S&OP process was planned within the next two years. 30% of the companies were planning to implement APS for PP&S within the next two years. 25% were planning to adopt a manufacturing execution system within the next two years. Furthermore, 24% of the participating companies were planning to implement a software for available-to-promise & order management within the next two to five years. 21% indicated that a software for supplier relationship management would be implemented in the same time horizon. Similarly, 16% of the companies were planning to implement software for IP and manufacturing execution systems within the next two to five years. The great majority of survey participants (79%) indicated that no implementation of APS for SCND was planned. Similarly, the survey outcome showed that about half of the food companies were not planning to adopt software for transport planning (53%) and distribution planning (50%).

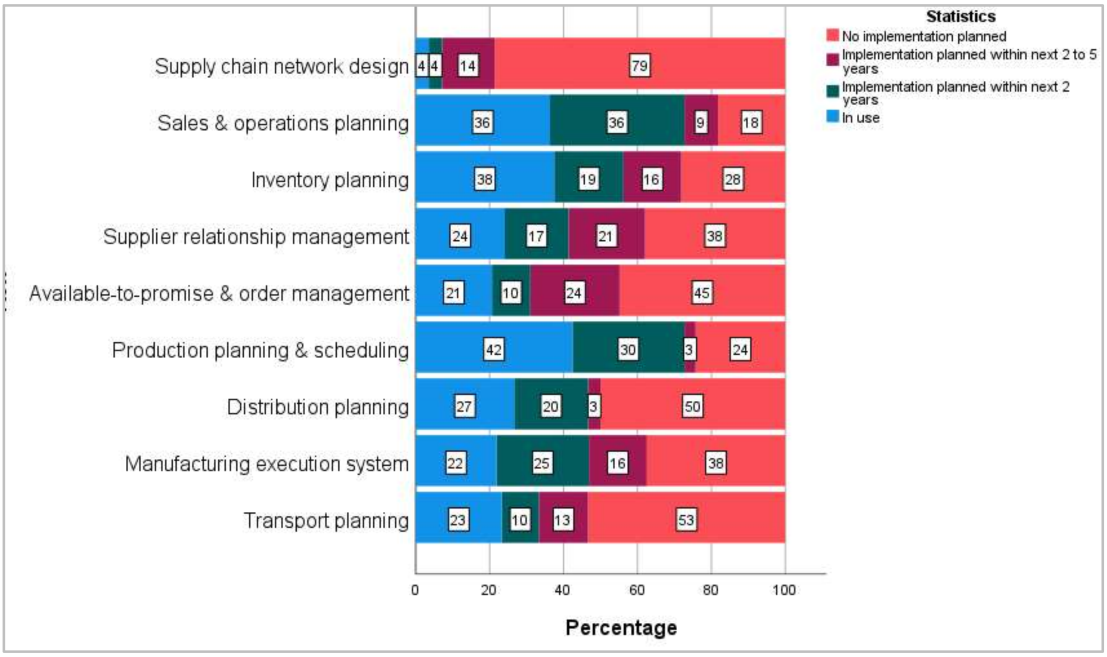

Figure 4.2: Percentage of companies per field of application that use dedicated software for SCP (based on author's own research).

The survey indicated that many of the companies were not using dedicated software tools for planning decisions (see Figure 4.3). Only 24% of the companies used APS as a leading planning tool. The systems are usually integrated with transactional systems (e.g. ERP systems) which provide the data for the tools (Wiers 2002). The majority of respondents (38%) used ERP systems to plan the supply chain. Another 22% of the surveyed companies indicated SCE systems as supporting tools for planning decisions. SCE systems are execution-oriented applications, including warehouse management systems (WMSs), transportation management systems (TMSs), and other applications to optimise the entire logistics (Gartner 2021). In contrast, APS tend to have a forward-looking character in order to harmonise supply and demand (Stadtler 2005). 16% performed SCP tasks with generic tools such as Excel or Tableau.

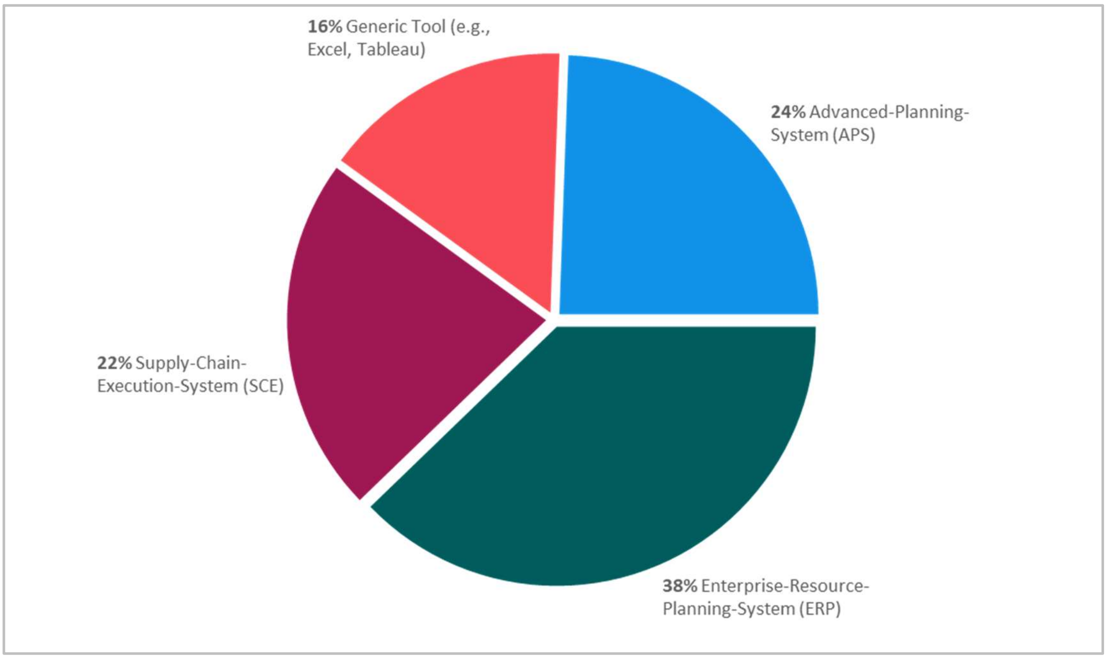

Figure 4.3: Overview of implemented leading planning software (based on author's own research).

Most of the implemented systems were software solutions from SAP (see Figure 4.4). Some companies used the planning software Advanced Planning and Optimization (APO), as well as its successor Integrated Business Planning (IBP) from SAP. Other survey participants utilised solutions from ToolsGroup or IBM as planning tools for their supply chain.

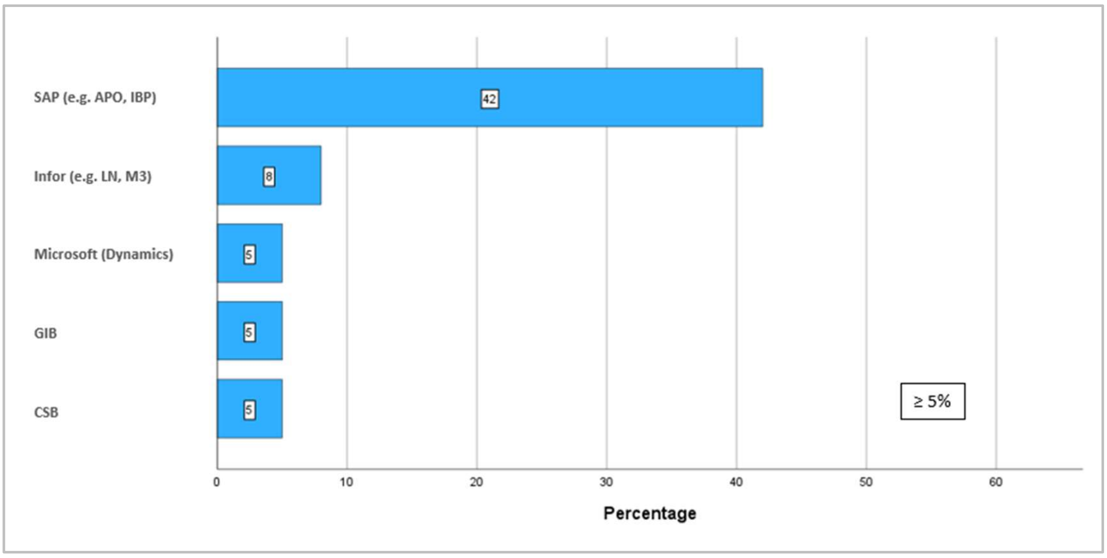

Figure 4.4: Proportion of software providers of the implemented APS-, ERP- and SCE-systems (based on author's own research).

According to the survey results the anticipated benefits of most software tools for SCP had been materialised (see Figure 4.5). The outcome further revealed that the performance of implemented solutions could largely meet the expectations of the food companies. The survey responses regarding time and cost of implementation projects were rather mixed. 37% of participants somewhat agreed that the implementation project took significantly longer than expected. The same amount of participants at least somewhat disagreed with that statement. 21% indicated that the cost of the software was higher than the expected budgets. This could not be confirmed by 46% of the participating food companies. Overall, the four-item measure for success of implementation projects reflected that most food companies were satisfied with the performance and associated benefits of implemented software tools for SCP.

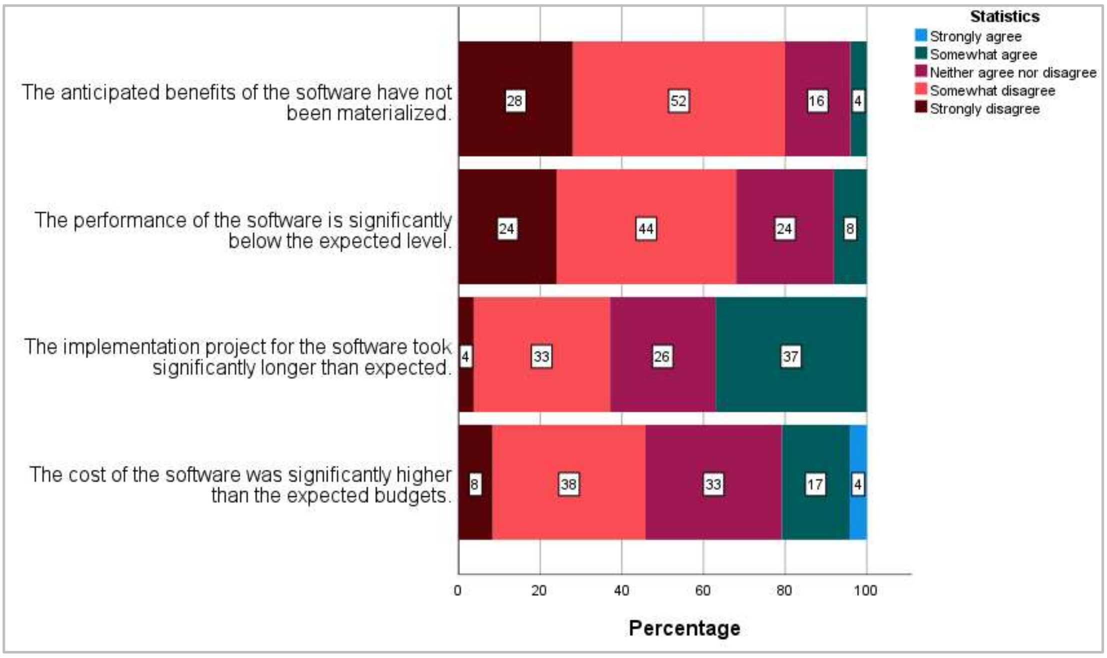

Figure 4.5: Success of implementation projects (based on author's own research).

The evaluation concerning the expertise of the consultants involved in the implementation projects revealed mixed results. The technological know-how of consultants was appreciated the most by the survey participants (see Figure 4.6). 76% of them at least somewhat agreed that the technological expertise of consultants was satisfactory. The responses regarding the change management and industry know-how were less clear. 57% of the participating food companies at least somewhat agreed that the change management know-how of consultants was satisfactory. 53% considered their industry expertise as adequate.

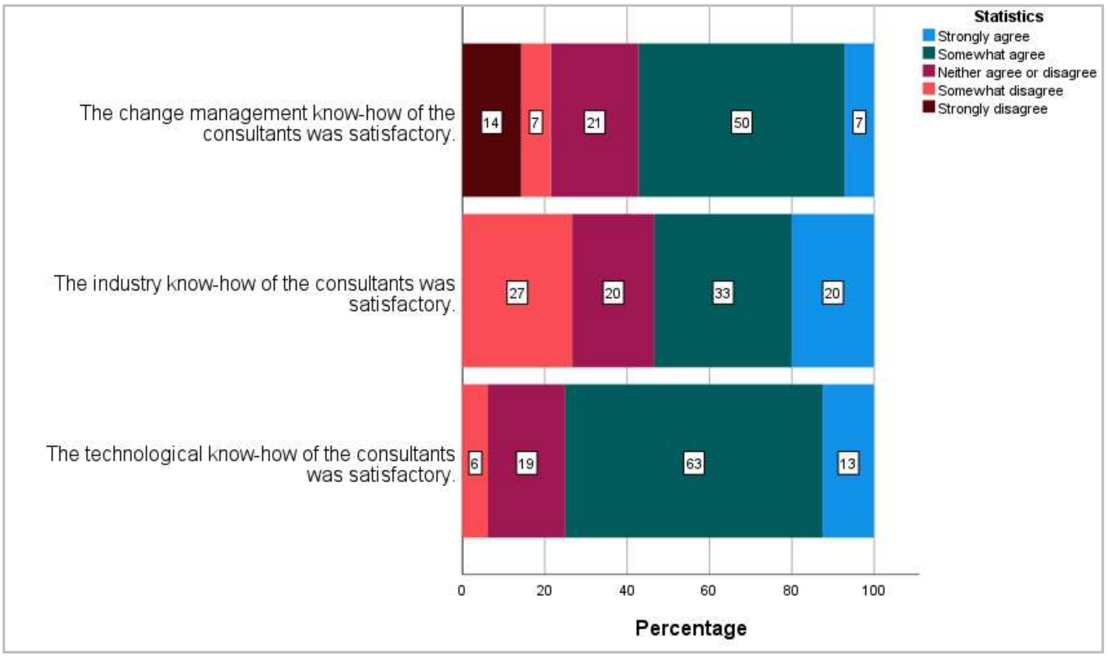

Figure 4.6: Expertise of consultants in implementation projects (based on author's own research).

The survey results indicated lack of time for an implementation project, lack of expertise as well as a low return on investment (ROI) as major barriers to implementation of APS modules (see Figure 4.7). This reveals that food companies particularly seem to lack certain resources to adopt software tools in order to support SCP practices. The low ROI as a barrier to implementation needs more investigation. This result could be due to low supply chain complexity. In contrast, practitioners were less concerned regarding company requirements that may not be covered by APS. Therefore, insufficient technical capacity of such software tools did not seem to be a significant barrier to implementation for managers in the food industry.

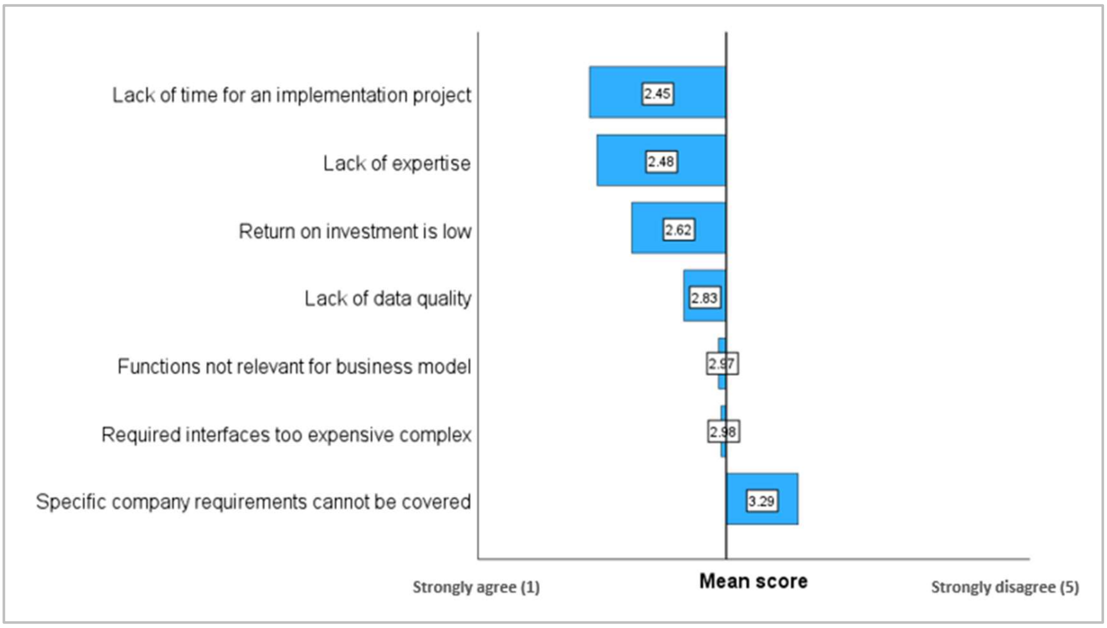

Figure 4.7: Barriers to implementation of APS modules (mean score) (based on author's own research).

An independent samples t-test was conducted to compare companies using and not using software tools for S&OP, IP and PP&S based on the measures of supply chain complexity (see Table 4.2). The results for the two measures of production uncertainty as well as of supply uncertainty were pooled. The test statistics indicated that the two groups differed significantly in terms of supply uncertainty. Companies using dedicated software tools for SCP tended to receive needed material for production at the right time and quantity. Likewise, supplied material was perceived at superior quality by companies with APS compared to those without such software tools, i.e. S&OP (p-value < 0.01), IP (p-value < 0.05) and PP&S (p-value < 0.05). In addition, food companies with APS tended to have less unplanned disturbances in the production process, i.e. PP&S (p-value < 0.05) and IP (p-value < 0.1). According to the test statistics companies whose supply chain was supported by S&OP software had a larger product portfolio and thus were exposed to greater detail uncertainty (p-value < 0.05). The test statistics did not reveal significant differences regarding demand uncertainty between users and non-users of APS. In addition, both groups of companies did not differ significantly in terms of shelf life of products.

Likewise, the means of revenue and number of employees were compared between users and non-users. The test statistics indicated that companies using software for

S&OP (p-value < 0.01) and IP (p-value < 0.01) had significantly higher revenues (see Table 4.3). Similarly, food companies with APS had significantly more employees, i.e. IP (p-value < 0.05) and S&OP (p-value < 0.1) (see Table 4.4).

Levene's test was applied to check the equality of variances. In two cases the null hypothesis of equal variances was rejected and the Welch test was applied. The means of the respective variables were additionally compared by the Mann-Whitney U test. The results could be confirmed. The use of software tools for SCND was excluded from this analysis due to a limited amount of cases. The test statistics can be found in Appendix 4.

Table 4.2: Comparison of supply chain complexity measures between users and non-users of APS (based on author's own research).

	S&OP			IP			PP&S		
Supply chain complexity	In use (n=12)	Not in use (n=20)	Cohen's d	In use (n=12)	Not in use (n=20)	Cohen's d	In use (n=14)	Not in use (n=18)	Cohen's d
Demand uncertainty	2.25	2.20	0.04	2.50	2.05	0.40	2.00	2.39	-0.34
Production uncertainty	2.92	2.73	0.19	3.13	2.60*	0.55	3.21	2.47**	0.81
Supply uncertainty	1.67	2.28***	-1.19	1.75	2.23**	-0.87	1.79	2.25**	-0.85
Detail uncertainty	3.33	2.40**	0.70	3.00	2.60	0.29	2.79	2.72	0.05
Shelf life	3.50	3.40	0.10	3.25	3.55	-0.29	3.36	3.50	-0.14

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed); outcomes were also confirmed by Mann-Whitney U test.

Table 4.3: Comparison of revenue between users and non-users of APS (based on author's own research).

	S&OP			IP			PP&S		
	In use (n=12)	Not in use (n=21)	Cohen's d	In use (n=12)	Not in use (n=21)	Cohen's d	In use (n=14)	Not in use (n=19)	Cohen's d
Revenue	6.75	5.33***	0.92	6.75	5.33***	0.92	6.14	5.63	0.31

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed); outcomes were also confirmed by Mann-Whitney U test.

Table 4.4: Comparison of number of employees between users and non-users of APS (based on author's own research).

	S&OP	IP	PP&S

	In use (n=12)	Not in use (n=22)	Cohen's d	In use (n=12)	Not in use (n=22)	Cohen's d	In use (n=14)	Not in use (n=20)	Cohen's d
Number of employees	7.17	6.41*	0.60	7.25	6.36**	0.71	6.64	6.70	-0.04

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed); outcomes were also confirmed by Mann-Whitney U test.

The survey outcome regarding PU of APS tools strongly supports the notion that APS systems are beneficial for food supply chains (see Figure 4.8). APS functions for S&OP, IP and PP&S were rated positively. In terms of the PU of APS functions for PP&S there was one outlier stating that the functions would not be useful at all. In contrast, the average PU of APS functions for SCND showed a central tendency on the Likert-scale. It should be noted that this finding could be traced to the majority of respondents being not familiar with software for SCND. PU was calculated here by the average ratings on all functions of the corresponding software tools (SCND, S&OP, IP, PP&S) across users and non-users.

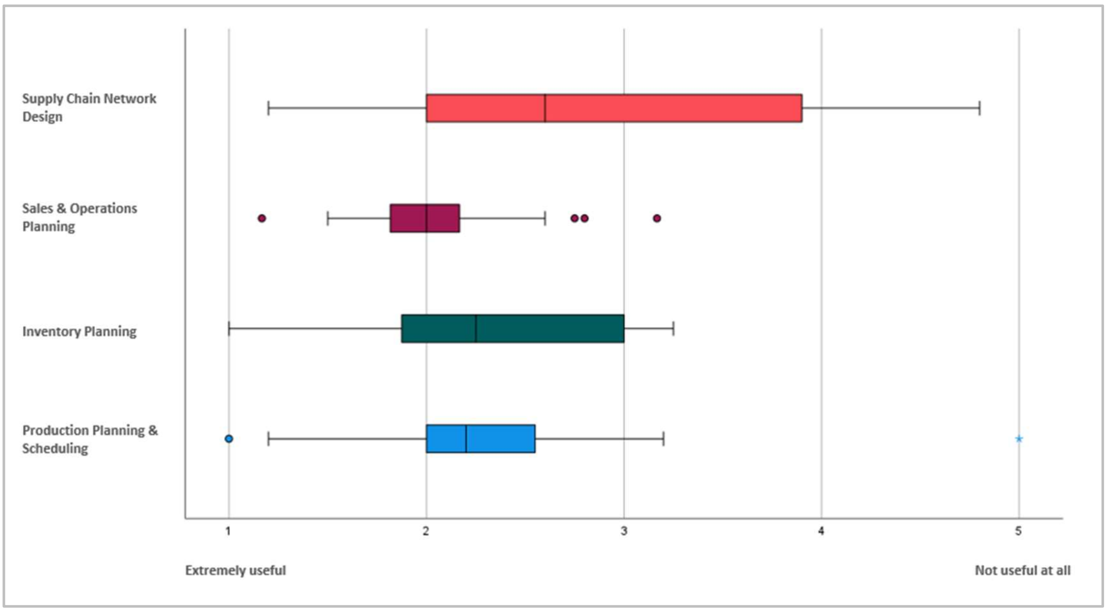

Figure 4.8: Average perceived usefulness of APS functions (based on author's own research).

The average ratings on PU of those companies using and not using the respective software tools were further compared (see Appendix 5). Overall, companies without an APS indicated a higher usefulness of the software functions. The differences were only significant regarding APS for IP (p-value < 0.05). The results were confirmed by the Mann-Whitney U test.

In addition, the PU of APS functions between companies with different levels of supply chain complexity (see Table 4.5 and 4.6) and between companies of different size (see Table 4.7) was compared. The test statistics between the independent samples t-test and the Mann-Whitney U test differed from each other. Due to the low number of observations, the results of the non-parametric test, the Mann-Whitney U test, are reported below.

The test statistics indicated a higher PU of APS, if companies were exposed to production uncertainty, i.e. PP&S (p-value < 0.01), IP (p-value < 0.05) and SCND (p-value < 0.1). Further significant differences in the PU of APS could be determined between companies with regard to average shelf life of products. Companies with an average shelf life of products of more than 30 days tended to find software tools for S&OP (p-value < 0.1) and IP (p-value < 0.1) more useful. A lack of software capability to deal with short product shelf lives could be a reason for this outcome. Similarly, the survey results showed that food companies with a larger product portfolio (more than 500 SKUs) tended to find APS functions for SCND less useful (p-value < 0.1). No significant differences in PU of APS could be identified between companies with different levels of demand uncertainty. Only in one case within the sample a supply chain was attributed complexity in terms of supply uncertainty. Therefore, the results regarding supply uncertainty can be ignored.

Larger organisations indicated a higher usefulness of software functions for S&OP. Surveyed companies with more than EUR 249 mil. in revenue perceived S&OP software as more beneficial than firms with lower revenues (p-value < 0.05). Likewise, companies with more than 499 employees reported a higher usefulness of systems for S&OP (p-value < 0.1). The test statistics are provided in Appendix 6. In the following sections the individual survey results regarding software modules for SCND, S&OP, IP and PP&S and are presented.

Table 4.5: Comparison of average perceived usefulness of APS functions between companies with different levels of demand, production and supply uncertainty (based on author's own research).

Perceived usefulness	Demand uncertainty			Production uncertainty			Supply uncertainty		
	Complex	Rather not complex	Cohen's d	Complex	Rather not complex	Cohen's d	Complex	Rather not complex	Cohen's d
	(n=17)	(n=7)		(n=10)	(n=14)		(n=1)	(n=23)	
SCND	2.87	2.74	0.11	2.52	3.06*	-0.49	1.20	2.90**	-1.60
	(n=22)	(n=8)		(n=14)	(n=16)		(n=1)	(n=29)	
S&OP	2.06	1.83	0.61	1.94	2.05	-0.29	1.83	2.00	-0.44
	(n=20)	(n=8)		(n=13)	(n=15)		(n=1)	(n=27)	
IP	2.33	2.25	0.11	2.07	2.51**	-0.68	1.88	2.32	-0.66
	(n=20)	(n=7)		(n=14)	(n=13)		(n=1)	(n=26)	
PP&S	2.27	2.35	-0.12	1.98	2.62***	-0.98	2.20	2.29	-0.12

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed).

Table 4.6: Comparison of average perceived usefulness of APS functions between companies with different detail uncertainty and different shelf life of products (based on author's own research).

Perceived usefulness	Detail uncertainty (# of SKUs in product portfolio)			Shelf life (in days)		
	More than 500	Up to 500	Cohen's d	Up to 30	More than 30	Cohen's d
	(n=13)	(n=11)		(n=5)	(n=19)	
SCND	3.11	2.51*	0.56	2.92	2.81	-0.10
	(n=17)	(n=13)		(n=5)	(n=25)	
S&OP	1.93	2.09	-0.44	2.26	1.95*	-0.86
	(n=15)	(n=13)		(n=6)	(n=22)	
IP	2.40	2.19	0.31	2.71	2.20*	-0.79
	(n=16)	(n=11)		(n=5)	(n=22)	
PP&S	2.27	2.31	-0.05	2.12	2.33	0.28

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed).

Table 4.7: Comparison of average perceived usefulness of APS functions between companies of different size (based on author's own research).

Perceived usefulness	Revenue (in EUR mil.)			Number of employees		
	More than 249	Up to 249	Cohen's d	More than 499	Up to 499	Cohen's d
	(n=13)	(n=11)		(n=14)	(n=10)	
SCND	2.68	3.02	-0.31	2.63	3.12	-0.45
	(n=17)	(n=14)		(n=19)	(n=13)	
S&OP	1.92	2.09**	-0.45	1.96	2.14*	-0.43
	(n=15)	(n=13)		(n=17)	(n=11)	
IP	2.36	2.24	0.17	2.28	2.34	-0.09
	(n=15)	(n=12)		(n=18)	(n=10)	
PP&S	2.32	2.25	0.09	2.16	2.54	-0.55

Notes: Significant at: *p < 0.1, **p < 0.05, and ***p < 0.01 (one-tailed).

4.3.1 Supply Chain Network Design

The result of the survey showed that the majority of respondents (63%) were barely or not at all familiar with software solutions for SCND. The limited know-how regarding software solutions to support strategic planning of the supply chain was reflected in the low use of such tools in practice. The survey suggested various factors as reasons why companies were not using software in this area. In addition to lack of expertise in using the software, lack of time for an implementation project and an insufficient ROI were viewed as main barriers. Some participants justified the decision to not adopt specialised software for SCND with the low complexity of their supply chain. The functions of software solutions for strategic SCP were considered as useful though. According to the survey outcome food companies would benefit most from APS supporting their strategic logistic planning including the determination of number and locations of distribution centres. The results for software supporting SCND are provided in Appendix 7.

4.3.2 Sales & Operations Planning

According to the survey results most respondents (44%) were moderately familiar with S&OP software. The survey showed that many standard functions of software tools to support the S&OP process were only partially covered by the implemented software solutions. For example, the tools used hardly allowed the inclusion of judgemental factors. In addition to the statistical forecast, this function allows further aspects such as the know-how of experts to be considered when assessing future demand. Other functions such as the automated resolution of bottlenecks and the creation of an unrestricted operations plan were less covered by the implemented systems. The first function prevents bottlenecks by automatically generating suggestions of feasible plans, e.g. by building up inventory or by scheduling additional shifts, to meet the demand. The latter function calculates the net demand considering stock levels and compares the required production quantities with the available capacities. In contrast, implemented solutions for S&OP largely enabled the input of other departments (e.g. sales, procurement) to improve forecast accuracy. Likewise, statistical forecasting based on historical data as well as accuracy measurement of the forecasts were mostly included in S&OP tools used by the surveyed firms. Overall, participants agreed that software functions of S&OP software were useful. The result of the survey showed that companies with APS supporting the S&OP process rated the functions as highly beneficial for their business. On average every provided feature was evaluated at least as moderately useful. The software function that enables food companies to gather input from multiple departments for demand forecasts was considered as most useful. Furthermore, the creation of an unrestricted operations plan was viewed as a valuable element of APS for S&OP.

Regarding the evaluation of implementation projects the results indicated that most of the anticipated benefits could be materialised in the participating companies. Survey participants were largely satisfied with system performance. In contrast, the duration of implementation projects was assessed by 45% of the companies as rather too long. The survey outcome suggested an insufficient ROI, lack of expertise to use the software and lack of time for an implementation project as main barriers to the adoption of S&OP software. Data quality as well as the set-up and maintenance of required interfaces were less likely to prevent food companies from implementing software to support their S&OP process. The survey outcome regarding S&OP software is provided in Appendix 8.

4.3.3 Inventory Planning

On average the survey participants were rather familiar with software for IP. The survey revealed that the systems used by the food companies covered the usual functions of software modules for IP only to a limited extent. Transfer management, value added services including features such as labelling, and inventory optimisation were rather not included in the software solutions used. The latter function includes the determination of optimal stock sizes and safety stocks considering preferred service levels and can be regarded as core element of APS for IP. The survey outcome may be attributed to the fact that many participating companies did not use specialised software solutions for IP, but rather relied on Excel or ERP systems with less sophisticated functions for IP. Basic functions for inventory management to categorise products and to view product history were largely covered by the implemented software tools. In addition, most tools included alert functions in case of oversupply or supply shortage of any product. The survey results showed that software functions that are commonly included in IP systems were to a great extent considered as useful by food companies. The projection of inventory levels for future periods and stock-out and overstock alerts were perceived as most beneficial by the survey participants. Transfer management functions including features for multi-location tracking or order picking as well as value added services such as labelling were assessed as less useful by the food companies.

Most companies (71%) were rather satisfied with software performance and the expected benefits with regard to the implemented systems were largely realised. The costs of the software tended to be within expected budgets. Results regarding the duration of implementation projects were mixed. For this area of application, the survey results indicated lack of time for an implementation project, insufficient ROI and lack of expertise as primary barriers to software implementation. In addition, the set-up and maintenance of interfaces to the existing IT infrastructure was considered as impediment. The survey results can be found in Appendix 9.

4.3.4 Production Planning & Scheduling

Most managers were moderately familiar with software tools for PP&S. According to the survey outcome 11 participants were at least very familiar with APS for PP&S. The results indicated that the systems used for PP&S did not fully cover the functions usually contained in specialised software. Survey participants stated that the implemented software solutions for PP&S only partially enabled dynamic lot-sizing and algorithm-based scheduling and sequencing of production orders. In contrast, most implemented systems allowed the refinement of production schedules by the input of supply chain managers (e.g. dispatchers). Functions to prioritise, track, and report against production orders and schedules were mostly covered by the PP&S software as well. The added value of the systems was recognised by the respondents. Most of the software functionalities for PP&S were considered as highly useful. The function enabling managers to manually adjust production schedules was perceived as most beneficial among the common features. The ability to reschedule orders enabled by drag & drop functionality in an interactive planning board was also considered as very useful by the survey participants.

The survey outcome regarding implementation projects of PP&S software was less clear. The performance of the software solutions used for PP&S was largely viewed positively. 75% of the surveyed participants with insight on the project found that anticipated benefits could be rather materialised. On the other hand, there were differing views with respect to cost and duration of software projects. Reasons for not introducing software for PP&S were diverse. Lack of relevance for the business model, lack of expertise, insufficient data quality and required interfaces were major motives against an implementation project. Practitioners were less concerned that company-specific requirements could not be covered by APS for PP&S. The survey outcome regarding software for PP&S is attached in Appendix 10.

4.4 Chapter Summary

Overall, only a small proportion of the surveyed food companies adopted specialised software for SCP. Many companies employed ERP systems or software tools such as Excel to plan their supply chain. Companies were reluctant to adopt APS due to different reasons. In particular, a lack of company resources, expertise on how to use the systems and time for new projects, was identified as major barrier to APS implementation. Several firms were also inhibited to adopt APS because of a low expected ROI.

The survey participants assessed most functions of APS modules as highly useful for their business. Implementation projects were mostly considered successful by surveyed managers. According to the survey results the anticipated benefits of most implemented software for SCP had been materialised. The outcome further revealed that system performance could largely meet the expectations of the food companies. The survey responses regarding time and cost of implementation projects were rather mixed. The outcome further showed that supply chains of those companies using sophisticated software for SCP were attributed less complexity. Likewise, firms using and not using APS differed significantly in terms of revenue implying that the adoption of dedicated software for SCP requires a certain financial capacity.

Due to the low response rate of the survey the sample size was relatively small. This research followed the recommendations for survey-based studies that rely on small samples by Beuckelaer and Wagner (2012) to ensure reliability and validity of the research findings. The survey participants can be expected to be well aware of SCP processes within their company and of potential associated software tools. Nonetheless, more empirical data was required to understand why companies decide for or against the implementation of APS modules. As a next step within this mixed methods research the survey findings were enriched by semi-structured interviews with managers of food companies, software vendors and consultants. The outcome of the qualitative interviews is presented in the next chapter.

5 Interview Results

5.1 Introduction

In this chapter the interview results of the semi-structured interviews with the food producers, the software vendors and the consultants are summarised. In the first section an overview of the different interview participants is provided. After that the interview output of the three food companies is described. Subsequently, the results from the interviews with the software vendors and consultants are presented according to the previously defined themes. Firstly, organisational and system requirements for APS adoption stated by the managers from software firms and the consultants are depicted. Secondly, drivers of APS adoption and barriers to APS adoption are detailed. Thirdly, suggestions by the interviewed software vendors and consultants how to facilitate and improve the implementation of SCP software are put forward. Lastly, the outcome of the interviews is summed up in the conclusion. The interview findings primarily served to answer the second and third research question.

5.2 Overview of Interview Participants

Different groups of experts were interviewed for this research. The semi-structured interviews were carried out via a video conferencing tool as specified in Chapter 3. In total 15 interviews were conducted between January and April in 2022 to deepen the insights gained from the survey data. Three managers of food producers, five managers of software vendors for APS, and seven consultants were interviewed (see Table 5.1). In the following section the participant profiles are presented.

Table 5.1: Participant profiles of interviewees (based on author's own research).

Group of experts	Participant profiles
Managers of food companies	1. Head of Demand Planning of a sausage producer 2. Commercial Manager and Head of Operations of a liquor producer 3. Head of Controlling of a winery

Managers of software vendors	1. Managing Director Europe 2. Supply Chain Consultant 3. Head of Sales and Consulting 4. Sales Manager 5. Director New Business and Global Accounts
Consultants	1. Partner 2. Partner 3. Partner 4. Senior Manager 5. Manager 6. Manager 7. Senior Consultant

5.2.1 Food Companies

One of the interviewed managers worked for a sausage producer located in Germany. The sausage producer was a medium-sized company, generated about EUR 250 mil. in revenue, and employed between 500 and 1.000 employees. The family business had a long history in the meat processing industry. Some years ago, the sausage producer positioned more broadly and expanded the product portfolio by vegetarian products. In the meantime, the firm generated more revenue with vegan and vegetarian products than with conventional meat sausage. The interviewee joined the company several months prior to the interview as Head of Demand Planning. Likewise, the interview participant was the project manager for the software implementation for demand planning, production planning and production scheduling.

Another interview participant was employed at a liquor producer based in Germany. A few years ago, the liquor producer was acquired by a multinational beverage group. The beverage group consisted of various beverage companies from multiple countries, employed approximately 1,000 employees, and generated a turnover of about EUR 250 mil. The product portfolio comprised different wines and liquors.

Since the acquisition by the beverage group, the German liquor producer additionally sold the products from the other firms within the beverage group. The interviewee had the position as Commercial Manager and Head of Operations at the German company. The participant had many years of experience in similar positions in the consumer goods industry. The company was in the tendering process for an S&OP software. The system should be implemented by all firms in the beverage group.

Moreover, a manager of a German winery was interviewed. The family business generated about EUR 150 mil. of revenue and had about 300 employees. The business bottled the wine of approximately 1,000 winegrowers. The biggest customers were food retailers in Germany. Half of the wine was exported abroad. The product portfolio included aromatised wine-based and non-alcoholic beverages next to traditional wine. The interview participant was Head of Controlling and had been employed for many years at the company.

5.2.2 Software Vendors

One of the interviewed participants worked for an Australian software vendor for SCP tools. The interviewee worked as a Managing Director of the European business. The software company offered an SCP suite encompassing different modules such as demand planning, inventory optimisation, production planning, etc. The system was initially developed for the meat industry and the majority of the customers was still from the food and beverage industry.

Another interview participant was employed at a Dutch software vendor for SCP. The interviewee had several years of experience as supply chain consultant for that software company. The software firm offered different applications for SCP. The core application was targeted for SCND. The system was employed by multiple companies in the food industry.

One further software vendor that participated in the semi-structured interviews offered various software modules for SCP. These included, amongst others, software for S&OP, IP, and production planning. The German company acquired another software vendor to improve system capabilities for the food industry. The interviewee had the position as Head of Sales and Consulting at the software firm.

Another interviewee was employed at a German software vendor offering a planning platform for inventory optimisation. Multiple system functionalities were offered as separate modules by the software vendor. Most customers of the software vendor were from the food and retail industry. The interviewee was employed at that firm as Sales Manager.

Furthermore, one interview participant worked for an American software firm. This software vendor sold a broad range of software, amongst others also ERP systems and APS. The company offered a supply chain suite for SCP comprising different modules. These included solutions for demand planning and forecasting, supply planning, production planning and control, etc. The participant had the position as Director New Business Sales and Global Accounts. The software vendor offered industry templates for the food and beverage industry which were widely deployed in that industry, in particular within the brewing industry.

5.2.3 Consultants

All interviewed consultants were employed at the same management consultancy. The consultancy was based in Germany and had between 50 and 100 employees in total. The consulting firm was focused on SCM and procurement. The company carried out projects in multiple industries across different countries. The consultancy had particularly strong expertise in the food and beverage industry since the majority of clients was from that industry. All approached consultants were at senior management levels in the consulting firm. Three partners, one senior manager, two managers, and one senior consultant were interviewed. All had significant consulting experience in the food industry. In addition, most of them had already accompanied various tenders for SCP software of client firms.

5.3 Food companies

The interviews with the managers of the food companies revealed insights regarding the adoption of APS in the individual contexts of the firms. In the following sections the results of the interviews with the three food producers are presented.

5.3.1 Food Company 1: Sausage Producer

The manager of the sausage producer stated in the interview that the company was tendering APS for demand planning, production planning and production scheduling. It was argued that sophisticated SCP was inhibited by an obsolete organisational structure before. Moreover, silo thinking was prevalent in the company. Different teams involved in the firm's supply chain (e.g. purchasing, production, logistics) pursued their individual objectives. As a consequence, cross-functional SCP processes were not present. The interviewee put forward that sales data were drawn from the ERP system and analysed with a generic reporting tool. Demand forecasting was not conducted. Production planning was carried out via Excel. Furthermore, planning decisions were largely based on the knowledge of individual employees instead of data.

Following the expansion of the product range with vegetarian and vegan products, SCM became increasingly complex. Given the lack of demand forecasting the company often produced sausages that were less demanded by consumers. Hence, there was an overstock of meat products, while the firm had not sufficient production capacity for vegetarian products. The packaging of products was partly carried out via an external service provider leading to additional complexity. Besides the enlarged product portfolio, the supply chain managers were challenged by the promotional business of food retailers contributing to demand fluctuations. Overall, business operations were characterised by an imbalance between the demand and supply side which led to an ineffective use of production capacities and considerable food waste.

The interview revealed that an analysis of the company's SCM conducted by external consultants suggested the introduction of APS to improve SCP processes. The software implementation was advocated by the new head of SCM. The sausage producer planned to adopt SCP software in three steps. Firstly, a demand planning module should be introduced. After that, a software module for production planning, and subsequently for production scheduling should be implemented. Prior to the implementation of the software modules the firm's SCM department was restructured. Different teams such as production, logistics, purchasing, demand and supply planning were integrated into a newly established SCM department. According to the manager the new organisational structure should foster the collaboration between the individual teams and served as foundation for an integrated supply chain.

Different software requirements were put forward in the interview. The ease of use for employees was emphasised as a crucial aspect for software selection. As part of the tender, workshops with different software providers were conducted. In these workshops demo versions of the software tools were presented. Additionally, the quality of forecasts was important for the business. The demand for sausage products was heavily influenced by promotions. Hence, the demand planning module should enable managers to differentiate between the basic level of demand and demand peaks caused by promotions. The software vendors were tasked to calculate forecasts based on the sales data of the sausage producer. Afterwards the forecast accuracy could be compared between software vendors. Additionally, the new software should be able to convert sales to net sales. Thereby, demand planners could identify major sales drivers within the product portfolio.

A more targeted use of production capacities enabled by enhanced demand forecasts was mentioned as overarching objective of the software implementation. It was highlighted in the interview that the company would contribute the required resources for this endeavour. The project began end of 2021 and the go live of the demand planning module was planned for the beginning of 2023. The manager expected the implementation of all three software modules to be finalised within two to three years.

When asked about major barriers to APS adoption, the manager explained that many organisations would evade change and the introduction of unfamiliar processes. Companies were most comfortable with the existing processes and therefore would rather retain their ways of working. Some statements by the interview participant are provided in Table 5.2.

Table 5.2: Examples of statements by the interviewed manager of a sausage producer (based on author's own research).

Theme	**Code**	**Sample statements**
Barriers to APS adoption	Lack of management support	"Many companies avoid change. It is believed that existing processes are working well."
Drivers for APS adoption	SC complexity	"The planning of the supply chain was more and more complex due to the increasing amount of veggie products. […] We have often experienced a lack of production capacities for veggie products, while too much has been produced in the meat segment."
	Review of SCM practices	"An external consultancy proposed the implementation of software to enable more sophisticated SCP processes."
Organisational requirements for APS adoption	Management support	"The new head of SCM supports the implementation of the new software."
	Expertise	"The project management office guides the software project. In addition, new managers, including myself, have been hired to support the software implementation."

	SCM processes	“We have not implemented a software for SCP before, because there was no SCM structure. Silo thinking was dominant in the organisation. Different teams like purchasing, logistics and production were acting on their own. […] The new SCM department should contribute to a closer collaboration between individual teams and lead to a better alignment of decisions.”
System requirements for APS adoption	Ease of use	“The usability of the new software is very important for us. The user-friendliness has been examined in demo workshops with the software vendors.”
	Functionalities	“The demand forecasts should be improved by means of the new software. […] We need to understand our demand and the required production capacities to cover the demand.”

5.3.2 Food Company 2: Liquor Producer

The interview with the manager of the liquor producer revealed that the firm was tendering an S&OP software. Until then SCP processes were rather simplistic. The rationale behind SCP was primarily to replenish inventory in the warehouses. Production plans were calculated via Excel and based on inventory data from the ERP system. The company supplied a modest range of liquor articles to key accounts, in particular to food retailers. Since the acquisition by the multinational beverage group, the business operations of the liquor producer had changed. The company began to sell articles from the whole beverage group. Likewise, articles of the liquor producer were also sold overseas by other companies within the beverage group. This led to an increased supply chain complexity according to the interview participant. The company had to manage consumer demand for a larger number of beverages. In addition, more customers besides food retailers were supplied with the beverages. The original products were still the major sales driver for the business though. It was mentioned that about 80 percent of the firm’s sales volume was covered by approximately 20 percent of the articles.

Considering the increased complexity following the acquisition, the liquor producer initiated a tendering process for an S&OP software for the whole beverage group. Different software requirements were specified by the interviewee. Firstly, the demand planning module should integrate the demand for the products of the different firms in the beverage group. Based on that the software should provide procurement plans derived from demand planning. Thereby, the liquor producer would know how much the firm would have to buy from the other companies in the international beverage group. Another requirement for the new software was reduced manual effort of supply chain managers for SCP. It was indicated that the company’s staff spent significant time on the maintenance of rolling forecasts. A new tool should alleviate this effort so that supply chain managers could focus on other valuable tasks. Furthermore, the interviewee emphasised that the software should present KPIs and the most important analyses in a dashboard. A global view of sales and inventories, insights regarding plant utilisation and turnover rate were mentioned as key metrics that the software should provide for the company’s staff. In addition, the software should be usable globally across different countries. It was indicated in the interview that the other firms in the organisation would also introduce the software modules. Hence, the software should be available in different languages. Likewise, the system had to be integrated with the ERP systems employed by the individual companies in the beverage group. It was put forward by the interview participant that various ERP systems were used by the firms in the organisation. While some beverage producers used ERP software from SAP, the liquor producer employed a system from a small-scale ERP provider.

The manager planned a period of one year from the start of the tendering process until the go live of the new software. According to the manager three conditions needed to be fulfilled to consider the implementation project as success for the organisation. Firstly, the amount of time that supply chain managers invested in Excel analyses for SCP purposes should be minimised. Secondly, the key figures and analyses shown by the new software should provide new insights for the SCM department to remedy supply chain deficiencies within the beverage group. Thirdly, the new software was supposed to generate increased forecast accuracy. Enhanced forecasts as well as transparency of demand for the beverages across the firms of the beverage group should significantly facilitate planning processes. Thereby, each firm within the beverage group was enabled to plan its individual supply chain more accurately. The liquor producer was aiming to transition to a demand driven supply chain via the new software. It was emphasised that the software implementation was supported from top management in the organisation. The beverage group was also planning to adapt its organisational structure, in particular the sales organisation, while the new software was implemented. After the S&OP software modules were implemented, the beverage group would additionally consider the adoption of APS for production scheduling.

According to the interviewee the significance of a fully integrated supply chain was not recognised by many practitioners in the food industry. It was essential to reduce inefficiencies along the whole supply chain. Regarding increasing production costs and changing consumer preferences sophisticated SCP by means of APS could provide significant added value for food producers. It was further presumed that many companies would avoid the adoption of SCP software due to the associated implementation costs. Several explanations by the interviewed manager can be found in Table 5.3.

Table 5.3: Examples of statements by the interviewed manager of a liquor producer (based on author's own research).

Theme	**Code**	**Sample statements**
Barriers to APS adoption	Lack of business case	"Before we have been acquired, our business operations were rather simple. We supplied a limited range of products to our key accounts. Our priority was to fill up

		storage in our warehouses instead of demand driven production.”
	Lack of management support	“The importance of a fully integrated supply chain is still underestimated. It is crucial to examine processes from purchasing to delivery considering rising costs of raw materials and shorter product life cycles.”
	Lack of business case	“The costs that are associated with the introduction of a new system prevent many companies from software adoption.”
Drivers for APS adoption	SC complexity	“Following the acquisition, we are not only supplying to our key accounts anymore. Additionally, the product portfolio has increased as we are also providing the products from other companies in the beverage group. Therefore, we need to plan the demand for a wider range of beverages.”
Organisational requirements for APS adoption	Management support	“Top management gives the fullest support for the software project.”
	SCM processes	“The sales organisation will be adapted as part of the implementation project.”
System requirements for APS adoption	Functionalities	“The demand planning software should incorporate the demand for the different beverages in the organisation. Thereby, procurement plans can be derived. […] The software should provide enhanced forecasting quality.”

	Functionalities	“The system should reduce the manual effort of our SCM to create rolling forecasts.”
	Functionalities	“The software should provide new insights for our SCM. The system should present a global view of sales and inventories in a dashboard.”
	Technical integration with ERP system	“The software should be integrated with various ERP systems from different firms within the beverage group.”

5.3.3 Food Company 3: Winery

The interview with the manager from the winery revealed that no APS was employed by the company. Instead, sales planning was carried out via Excel based on data from the ERP system and know-how from sales staff. Requirements planning for raw materials for the bottling of wine was also conducted by means of the ERP system. The system originated from a small software provider. According to the interviewee initial rough demand plans were generated by the sales team twice per year. In addition, rolling monthly sales planning was conducted. It was emphasised by the manager that the sales planning took a lot of capacity for the sales staff. The quality of the sales plans was still considered as low. High inventories, sparse communication between the sales and production department as well as poor delivery rates were identified as further pain points of the firm’s supply chain. The winery had long-term contracts with retailers. Purchase orders from the retailers were sent at short notice so that material planning processes to meet the demand were mostly only conducted one week prior to the delivery date.

It was indicated by the manager of the winery that the introduction of a software to support SCP processes was examined a few years ago. A consultancy had suggested the implementation of an S&OP software. In particular, the software implementation was considered to integrate sales planning with production planning. It was highlighted by the interviewee that higher forecast accuracy and automated suggestions from a software for production planning would benefit the company.

Lastly, the management of the winery decided against the implementation of an APS although the software functions were considered as useful for the business. Different factors prevented the firm to implement a software for S&OP. Firstly, the interviewee argued that the company did not have the expertise required for the introduction of an SCP software. It was indicated that the company neither had IT nor supply chain know-how within the firm to implement and operate a new system. Consequently, the winery had to invest in external expertise. In addition, the manager stated that there was a lack of management capacity for the project. Different initiatives were prioritised at that time. Besides the lack of human resources, the firm also did not have the financial capacity for the investment in a new software. Insufficient data quality was another factor against the implementation of a new SCP system. Overall, the software was considered as useful support for the firm's supply chain. It was elucidated that the ROI for the introduction of an S&OP software was hard to quantify though. Therefore, an implementation project was not pursued by the management of the winery. Some views of the interviewee are depicted in Table 5.4.

Table 5.4: Examples of statements by the interviewed manager of a winery (based on author's own research).

Theme	Code	Sample statements
System requirements for APS adoption	Functionalities	"I would expect greater forecast accuracy of the sales forecasts calculated by the tool."
	Functionalities	"Automated suggestions for our production would be desirable."
Barriers to APS adoption	Lack of human resources	"We neither have the required IT nor SC expertise for such a project in our company."
	Lack of human resources	"We do not have enough management capacity for a software project. Other topics are more important."

	Lack of data quality	"Our data quality is not sufficient for the introduction of a new software for SCP."
	Lack of business case	"We do not have the financial resources for the costs associated with a new system. Additionally, we would have to invest in external know-how and the ROI of an S&OP software is difficult to calculate."

5.4 Software Vendors

In the following sections the results from the interviews with managers of software companies are presented. Specifically, their views on system requirements and organisational requirements for APS implementations, as well as drivers and barriers to APS adoptions are outlined. In addition, advice by the software vendors how to facilitate implementation projects is explained.

5.4.1 System Requirements for APS Implementation

Software for SCP should fulfil multiple requirements to be expedient for food companies (see Table 5.5). It was highlighted by the interviewed managers that software requirements would differ depending on the specifics of a company's supply chain. Different functionalities of APS to support SCP processes were mentioned by the interviewees. It was stated that the forecasting algorithms incorporated in software modules for demand planning would lead to enhanced forecast accuracy. Weekly or monthly demand forecasts would be sufficient for some food sectors (e.g. snack industry). In contrast, other food producing companies, such as firms operating in the meat or dairy industry, would necessitate daily or even intraday forecasts. Promotion planning was considered as another important function of APS for food companies. Sales promotions could lead to short-term demand peaks on top of the regular demand. Additional demand such as promotions or one-off effects could be reflected in the sales plan to obtain an accurate overall picture of the demand.

Furthermore, the responses given by the software managers revealed that the mapping of product characteristics was a significant software requirement for firms in the food industry. Food companies would often produce a wide range of products. It was argued that APS could optimise inventories by considering product specific information such as shelf lives, maturing periods or service levels. Thereby, food waste could be reduced. In addition, software tools for SCP could optimise production plans by taking various parameters (e.g. machine constraints, set-up times, cleaning processes) into account.

It was further put forward by the interviewed software vendors that APS should incorporate different supply chain strategies. While many companies would follow a pull strategy to minimise inventory levels, other food producers required a combined push and pull approach. Meat processing companies were mentioned as an example for the latter. In the initial echelons of the supply chain, the rearing and slaughtering stage, a push scheme was followed. In the later stages, including the processing and distribution of goods, the pull principle was employed. Software for S&OP should coordinate the push mechanisms with the downstream production processes and market needs. In addition, software tools could foster cross-functional integration as business processes could be mapped holistically from financial planning to production planning. It was explained in one interview that the system would offer various opportunities for collaboration between different departments such as demand planning, sales, and production. Thereby, the alignment on a final scenario could be accelerated via SCP software. It was emphasised by the interviewees that the requirements of diverse food sectors (meat, dairy, etc.) were addressed by individual software templates. Thereby, supply chain and food characteristics could be mapped and food producers were enabled to balance the demand of products with the supply side. It was argued that there were multiple use cases how APS could optimise food supply chains. The benefits that can be associated with the different functionalities of APS were numerous: Higher availability of goods with a simultaneous reduction in working capital, reliable planning figures, automation of processes, reduction of manual time-consuming work through management-by-exception, early recognition of opportunities and risks, etc.

Additionally, the software should be easy to use. The software managers mentioned several requirements for APS to be considered as user friendly. The interviewees agreed that the user interface should be well-structured, and should look intuitive as well as modern. The software should guide the user systematically regarding next tasks. While only exceptions should be processed by the user, software tools should allow for flexibility (e.g. adjustable prioritisation of orders). Furthermore, the user should be able to view significant KPIs at a glance to serve as a basis for decision-making. It was advised by one manager that different modules should have a similar structure to facilitate the familiarisation with a new system. Users should also have the possibility to configure their workplaces themselves. All software vendors assured that the software modules were constantly developed further. One of them explained that a dedicated design agency with staff originating from game development was employed to ensure a modern user interface. Another interviewee emphasised that the software was easy to use as the application was built by supply chain practitioners with the mindset of the user, and not by mathematicians.

The technical integration of APS with the existing IT landscape was considered as another requirement when contemplating the implementation of software for SCP. Although each software vendor assured that the software could be connected with all ERP systems, it was conceded that the creation of interfaces could lead to higher costs and longer project duration. Additionally, it was stated that software firms would need to ensure that the data processed within APS including historical sales data, product or supply chain attributes were secure. Security requirements for software products should be constantly reviewed and updated accordingly. Lastly, software companies should give their customers sufficient system support. This could be achieved in different ways. For instance, software firms could provide their customers access to knowledge databases, web-based trainings and online communities. Likewise, there should be an established way of communication regarding updates on incidents, service requests and product releases.

Table 5.5: Views of interviewed software vendors on system requirements for APS implementation (based on author's own research).

Theme	Code	Sample statements
System requirements for APS adoption	Functionalities	"Based on the turnover rate some food sectors, for instance meat processing firms, require daily or intraday forecasts. For other sectors such as the snack industry weekly or monthly demand forecasts are adequate."
	Functionalities	"The software should cover different supply chain approaches. Most firms operate via a pull supply chain to reduce stocks. Some food industries, for example the diary and meat sector, require push and pull elements equally though."
	Functionalities	"Different products and their specifics should be mapped in a software. We have individual software templates for different food industries."
	Ease of use	"The user interface should be well-structured and should systematically guide the user. The key aspects for decision-making should be visible at a glance."
	Technical integration with ERP system	"There is never one SAP standard. The creation of interfaces between the ERP system and our software modules is always a cost driver and risk factor of an implementation project."

5.4.2 Organisational Requirements for APS Implementation

The interviews with the software managers revealed several requirements that should be fulfilled by food companies for the introduction of APS (see Table 5.6). According to the software vendors different competencies should be present in a business when SCP software is introduced. Firstly, IT expertise was required to support the technical integration with the existing IT systems. One of the interview participants stated that the customer would be responsible for the technical integration with the ERP system. This would require technical expertise to create and maintain interfaces on the customer side unless a company would invest in an external IT service provider. Secondly, companies should have supply chain professionals with an accurate understanding of existing supply chain processes. These should also guide software firms how future processes should look like. It was argued by the interviewees that the software modules and more specifically the desired functionalities should be defined in the tender by the customer. According to one interviewee proficiency in SCP and statistical knowledge was required to operate the software. It was highlighted by another interview participant that the software could be flexibly customised by the user. The software was viewed as a configurable framework by the manager. Food companies could determine exceptions that require intervention by their staff and configure these rules in the system on their own. Thirdly, data specialists should support the implementation of the new system. Data quality was described as a prerequisite for APS implementation. Since APS were usually integrated with ERP systems, the data from the latter should be clean and well-structured. Firms should also be aware where the required data can be retrieved that is processed by APS. Data analysts should answer respective data queries. Data quality was considered as another cost driver and risk factor for APS implementation projects by the software managers.

Moreover, it was indicated that the implementation of certain software would necessitate respective organisational processes and structure as basis for digitalisation. If a company was willing to introduce a software for demand planning, this would require an appropriate demand planning department. The software managers further agreed that management support was another critical requirement for software implementation. The upper management in a business should actively support the organisational change towards a new software. Furthermore, the management had to approve the resources that were necessary to implement a new software. If the need to change current processes was not realised by top management, this might also have detrimental effects on the willingness to change on key user level in an organisation. It was argued that key users should be willing to accept the new software and the associated new ways of working. The staff should be eager to learn and to operate the novel system. The interviews revealed that the training effort for APS could differ between applications. One participant estimated a training effort of five hours to be able to use the system. The company staff would need between 20 and 25 hours to operate the system finally in an advanced manner. For other software tools the training effort could take several weeks.

Another prerequisite for APS implementation that was mentioned by the software vendors was business size. The introduction of software for SCP would constitute a significant investment. It was explained that a business would need to be capable to finance the new software tool. Therefore, organisations should have the corresponding financial resources. The interviewees reported different reference values in terms of business size of their customers. These differed depending on the scope of the systems offered by the software firms. It was stated by one software vendor focused on S&OP that companies should have a revenue of at least EUR 50 mil. Another interview participant reported that revenues of client firms were usually between EUR 500 mil. and EUR 5 bil., while some companies would also generate revenues above EUR 10 bil. One of the software vendors that provided software modules with selected functions for inventory optimisation stated that the business size of potential customers was neglected. The software firm would rather focus on inventory value. Potential customers should have an inventory value of at least EUR 500 k. Likewise, the supply chain should be characterised by a certain level of complexity according to the interviewees. The growth potential of a business was a further aspect that should be considered in the business case calculation of an SCP software.

Table 5.6: Views of interviewed software vendors on organisational requirements for APS implementation (based on author's own research).

Theme	**Code**	**Sample statements**
Organisational requirements for APS adoption	Data quality	"The data foundation is very important for the introduction of our software. The data structure should be clear."
	SCM processes	"If you want to implement software for demand planning, you need a reasonable department for demand planning. Decent processes are the basis for software implementation."
	Management support	"The management has to unlock the resources and drive the project."
	Expertise	"The employees typically need 5 hours to be able to operate our software module for network design. With a learning curve 20 to 25 hours in total are required to be good at it."
	Company size	"Customers should generate revenues between 500 m and 5 b. Companies that are growing fast and are still using Excel are considered as sweet spot. That is the point when people are looking for new software."

5.4.3 Drivers of APS Implementation

In the following section the results from the interviews with software vendors regarding drivers of APS adoption are outlined (see Table 5.7). The motives for the implementation of software tools for SCP were diverse according to the interview participants. Firstly, the interviews revealed that businesses would implement APS to address different challenges within their supply chains. Constantly changing market requirements, capacity overload, uncertain availability of products and promotion planning were mentioned as difficulties that organisations had to deal with. It was inferred by one software manager that organisations were sometimes forced to implement software for SCP due to the multitude of parameters to be considered and the complex market environment. Overall, there was great consensus among software vendors that companies tended to implement APS, if they were in trouble. It was highlighted that the managing directors of a company would often not realise the need for SCP software unless their businesses ran into serious difficulties. One interviewee indicated that drivers for APS adoption would differ across countries. While German businesses had the tendency to implement APS only in difficult times (e.g. high inventory levels, availability issues, lack of operational staff to meet service levels), managers in other countries such as Switzerland and Netherlands would act more result-driven and adopt APS proactively to attain corporate goals. This view was not supported by other interview participants though.

Companies could also view specific use cases for their business that gave them the impetus to adopt particular software modules for SCP. Hence, certain companies with a large and complex supply chain might consider network design as a core competence for their business and would decide to invest in a software to support ongoing network design decisions. Furthermore, an interviewee put forward that the COVID-19 pandemic had been an enabler for APS adoption. As a consequence of the pandemic companies experienced huge delivery issues. This led organisations to reflect upon their supply chains and shifted the focus towards SCP. It was argued that food companies could actively simulate global supply chain crises and thereby enhance their resilience against events such as the pandemic or the global chip shortage. Managers had recognised the significance to react quickly to supply chain disruptions and therefore increasingly relied on APS to gather actionable insights for different supply chain scenarios. Moreover, business growth was described as a driver for APS adoption. One software manager explained that companies would normally start with Excel to plan their supply chain. The more companies grew, the more challenging it was for them to coordinate demand and supply processes with each other. When the business had reached a certain size, Excel was perceived as insufficient, too slow and would lead to dissatisfaction among the employees. Then firms would start to look for software tools that are targeted for their supply chain processes and could lead to superior as well as faster results. The impact of software tools on job attractiveness was confirmed by another interviewee. Working with a specialised system was more attractive compared to the work with generic tools (e.g. Excel). Supply chain managers were enabled to proactively recognise problems by means of APS. This would lead to increased job satisfaction as employees would be less concerned with firefighting.

The interview results from the software managers further revealed that new management would often trigger a transformation process in a business. Older management generations were considered to be less open for change and would rather aim to maintain the existing ways of working. The review of existing supply chain processes by the new management would then lead to the implementation of software to enhance SCP processes. Likewise, the change of the ERP system could lead to an adjustment of supply chain processes. It was argued that companies might improve the SCP capability together with a general change of the ERP system.

Table 5.7: Views of interviewed software vendors on drivers for APS implementation (based on author's own research).

Theme	Code	Sample statements
Drivers for APS adoption	SC complexity	"When inventories are too high or companies are unable to deliver the demand, then organisations start to think about new software for SCP."
	SC complexity	"Companies were reaching their limits due to the COVID-19 pandemic. Many firms experienced delivery problems and began to focus more on planning as a consequence. They need to know how

		far in advance they should order for specific materials.”
	Specific use cases	“Specific use cases also push companies to explore tools which are made for that.”
	Specific use cases	“Almost every company starts with Excel. Then they realise that Excel is too slow and that they need a tool that focuses on the problem that they are dealing with.”
	Review of SCM practices	“The old management often says “we have always done it this way”. New management from outside the company usually wants to change something.”

5.4.4 Barriers to APS Implementation

In the following section barriers to APS adoption based on the gathered insights from the interviews with the software vendors are presented (see Table 5.8). The interview participants considered the costs associated with the software implementation as a major barrier preventing food companies to adopt APS. Many companies were either not able or not willing to afford a new software. It was also assumed that firms might not recognise a business case for the investment in a software to support SCP processes. Lack of expertise within companies was viewed as another barrier to APS implementation among the software vendors. Many firms would lack the inhouse knowledge to operate software tools for SCP. Moreover, the software managers indicated that firms also lack the awareness that existing processes were outdated, and that new ways of working were required to overcome challenges. It was presumed that organisations might also lack know-how regarding the existence of SCP software.

Another barrier for APS adoption mentioned by the software vendors was lack of management support. The management of a business would have to advocate APS implementation. It was emphasised by the software managers that new approaches to enhance SCP were often inhibited by the management. Therefore, it was crucial that managing directors were convinced of the software benefits and, beyond that, committed to the introduction of a new system.

A further barrier to the implementation of SCP software was lack of necessity. For some firms the use of Excel was perceived as sufficient to reconcile demand and supply processes. Particularly smaller firms with less complex supply chains might not feel the need to adopt a dedicated software to support SCP processes as long as generic tools such as Excel met the requirements for the respective supply chain. The software managers further indicated that market pressure was a prerequisite for APS adoption. Without competitive forces companies would rarely start to improve supply chain processes (e.g. enhance service levels for customers). Similarly, if certain metrics such as loss due to the perishability of food were low, companies were not induced to rethink their SCP practices, and to implement a new software.

Several organisations used ERP functions for SCP. It was argued that some organisations invested heavily in an ERP system and would not be willing to adopt an additional software. These firms would rather aim for software standardisation. The interviewees clarified that SCP software would offer more functions for supply chain managers. Additionally, it was assumed that firms lack expertise regarding the added value of APS compared with ERP systems.

Likewise, one software manager suggested that some supply chain professionals were afraid to lose control with SCP software. Due to the complex software algorithms that were incorporated in the systems, for instance to predict future demand, APS were considered as black box. With Excel supply chain managers had the control over the model used for calculations and thereby also over SCP decisions. Thus, dwindling influence on supply chain processes was regarded as another factor preventing companies to implement APS.

Table 5.8: Views of interviewed software vendors on barriers to APS implementation (based on author's own research).

Theme	Code	Sample statements

Barriers to APS adoption	Lack of human resources	"Companies are sometimes not aware that current ways of working need to be reconsidered to meet business objectives."
	Lack of management support	"If the CEO is not convinced of our software, then the system will not be adopted."
	Lack of management support	"There has to be market pressure, for example from the customer side. Otherwise, companies will not adopt new software."
	Lack of business case	"For companies with less complex supply chains Excel or basic functions of ERP systems are sufficient. SCP solutions cover more advanced functionalities for SCP."
	Complexity of interfaces	"Some organisations want to standardise on systems, and therefore do not implement additional third-party software."

5.4.5 Software Implementation Projects

This section details insights from the interviews with the software vendors regarding major challenges in APS implementation projects. Moreover, practical advice by the software managers how to prepare and facilitate software projects is provided (see Table 5.9).

The interviews revealed various deficiencies of implementation projects identified by the software vendors. One major challenge reported by the software firms was lack of management support. Top management would usually require rapid returns on investment by the new system. The short-term expectations associated with the implementation of the new software were often not realistic. This could cause conflicts and led to reduced support for the project in the medium term. According to the software vendors another challenge was lack of understanding concerning process requirements. It was crucial to discuss the specifics of the essential business processes in detail. Process know-how was highlighted as a prerequisite to customise the SCP tool according to the customer's needs. The interviewees were further concerned about the lack of availability of experts on the customer side. In particular, key users had often no capacities to provide their requirements for the new system. Similarly, expert personnel leaving the customer was considered as a risk for software projects. It was explained by one software vendor that the IT department of the client was normally responsible for the set-up of interfaces between the ERP system and their SCP tool. If the IT staff had no time to configure the interfaces, this could jeopardise the project plan. One further frequently observed obstacle by the software managers was the provision of data and poor data quality. The latter was mentioned as a requirement for proficient system output.

Different recommendations to facilitate APS implementation projects were put forward by the software vendors. Firstly, the software vendors stressed that management commitment was required throughout the whole period of the transformation project. It was essential to gather the adequate resources for the software implementation. Therefore, it was important to show the business case of the project. This should demonstrate the need for change. One software vendor of systems for inventory optimisation advised companies to involve controlling staff in the calculation of a business case. It was argued that the controlling team could provide useful input concerning inventory levels and the associated costs that should be considered. It was emphasised that a dedicated project team should be determined by the customer. It should be clear who is part of that team. One interview participant stated that the project team would typically require a demand planner, a supply planner, IT experts and the project management. These experts should be released from their day-to-day business to be able to focus on the software project. If possible, additional experts could also be hired for the project. It was further advised by one software vendor that the project manager should have an appropriate standing in the organisation to foster the acceptance for the new tool. Recent university graduates could be part of the project team but should not assume a leading role in the project. Furthermore, companies should plan required capacities of IT staff for the configuration of interfaces. According to one interviewee the introduction of software modules could be accelerated, if the interfaces were already implemented.

In addition, the implementation of software modules for SCP could be significantly facilitated by high data quality. Therefore, companies should put more emphasis on master data maintenance to be able to provide clean and well-structured data as foundation for the implementation of SCP software. Furthermore, employees should be encouraged by the project management to be open for new systems and processes. It was important to increase the employees' knowledge concerning possibilities and benefits of the planning tool. The staff should also get the time to learn how to operate the new tool. Thereby, employees would gain trust into the SCP system. At the same time the project management should manage the expectations of stakeholders. The interviews revealed that software to support supply chain network decisions could provide value within a few weeks. Other software modules (e.g. for S&OP) delivered quick wins after twelve months and the full result could be achieved after two to three years. It was further advised to develop a strategic roadmap that could guide companies to advance the digitalisation of their SCM organisation in a targeted manner. One interview participant put forward that the implementation of software for SCND was not always required. Companies had different options to conduct strategic SCP. It was argued that analyses in Excel spreadsheets could be sufficient, if the supply chain network was not complex. If network design was not considered as ongoing process but rather as a one-off project, then a consultancy could be tasked to restructure the supply chain. Likewise, if the company had invested a lot in an ERP system that offers functionalities for supply chain network optimisation as part of the package and network design was not regarded as core competence, then the ERP software could be the best option. If the supply chain was complex, and network design was viewed as an important capability, also for future optimisations, then it was the best choice to invest in a dedicated software solution.

The interviewees advised to conduct a proof of concept prior to the adoption of a new software. Thereby, the system output could be investigated, and companies could gain confidence into the new tool. The software performance should also be evaluated continuously based on KPIs. Most APS providers considered six to twelve months as standard duration of an implementation project.

Table 5.9: Views of interviewed software vendors on how to facilitate APS implementation projects (based on author's own research).

Theme	**Code**	**Sample statements**
Implementation projects	Ensure availability of resources	"The right experts should be selected for the project. The project team usually consists of a demand planner, a supply planner, IT staff, and the project management. Project managers should have a certain standing in the company."
	Highlight process requirements	"It is important to focus on the essential processes of a company. Many firms are not sure how the software should be customised. You have to teach them first what the software can provide."
	Ensure high data quality	"The provision of data and data quality are a major challenge for implementation projects."
	Maintain management support	"All stakeholders should be aligned regarding expectations and purpose of the software."
	Develop strategic view for targeted software adoption	"Companies should elaborate a strategic roadmap for their supply chain. It is important to reflect about objectives of the firm."

5.5 Consultants

In the following sections the results from the interviews with the consultants are summarised. Firstly, gathered insights regarding system and organisational requirements for APS implementation are outlined. Subsequently, their views on drivers and barriers to APS implementation are depicted. Lastly, suggestions by the interviewed consultants how to facilitate software implementation projects are detailed.

5.5.1 System Requirements for APS Implementation

The interviews with the consultants revealed various system requirements for APS implementation (see Table 5.10). Firstly, it was argued by the interviewees that requirements for SCP software were related to company size. Large companies would often opt for end-to-end solutions covering all processes in the supply chain, while smaller companies would rather invest in software targeted for selected processes. This was due to differing supply chain complexity and financial capacity.

Secondly, it was stated that the relevance of software features could differ between industries. Different software requirements were shared by the consultants in the interviews. Demand planning software should incorporate modern forecasting algorithms and consider external factors such as weather data or public holidays, besides historical sales data. The impact of special events on consumer demand could vary between different food sectors. It was elucidated that major football events (e.g. the football world cup) and hot weather could lead to a significant increase in the demand for the brewing industry. A demand planning software should further include key metrics on forecast accuracy enabling practitioners to gauge the performance of the forecasting engine correctly. Another requirement for IP software for food companies was the consideration of demand fluctuations and shelf lives. It was crucial to know for food producers when stocks would need to be built up to cover demand peaks despite limited capacities. At the same time shelf life restrictions should not be violated. Therefore, a synchronous planning of capacities and inventories based on consumer demand, service levels, shelf lives etc. was required. In addition, it was highlighted by the consultants that SCP software should map a firm's business processes. For instance, production planning software for dairy companies should cover the different production stages from the delivery of milk through pasteurisation, blending processes, drying, maturing processes up to the bottling of the products in a planning board. Furthermore, APS should map the company-specific product structure (e.g. white wine and red wine). Some food companies might require the opportunity to aggregate forecasts not only on article level, but also based on sales channel or sales region. One consultant also mentioned that it should be possible to customise APS in case of a changing sales structure. If a firm chose to expand globally, the system should be scalable accordingly. It was indicated by another interviewee that S&OP software should offer the opportunity to run "what-if" scenarios that could be reviewed by the management board in the S&OP meeting.

The consultants further put forward that a software vendor should have references from the same industry. Based on that information firms could better assess whether software tools can meet the requirements for a specific food sector. Another important aspect for APS was the ease of use. The "look & feel" for the users of a software was considered as fundamental by the interviewees. The system should have a well-structured user interface and should not overwhelm users with too much information. Furthermore, the user interface should be configurable by the user. It was also indicated that the technical integration of APS with individual ERP systems was essential as software calculations were based on data from ERP systems.

Table 5.10: Views of interviewed consultants on system requirements for APS implementation (based on author's own research).

Theme	**Code**	**Sample statements**
System requirements for APS adoption	Functionalities	"Demand planning modules should take external factors such as weather, public holidays or special events like the football world cup into account."

	Functionalities	"The software should be scalable. In case of global expansion the tool should be configurable according to changing sales requirements."
	Functionalities	"S&OP software should cover simulations that can be presented live in S&OP meetings."
	Technical integration with ERP system	"It is important to examine how the software can be connected to the ERP system."
	Ease of use	"Most often the best user interface wins. The interface of the software tools should be well-structured and should not be flooded with numbers."

5.5.2 Organisational Requirements for APS Implementation

The interviews with the consultants also provided insights about organisational requirements that should be fulfilled for APS adoption (see Table 5.11). It was argued by the interview participants that firms should have different know-how in their organisation for the introduction of SCP software. IT expertise was required to support the technical integration of APS with the ERP system. The software vendor would rely on the know-how of IT professionals, for instance in case of queries regarding existing IT systems. Companies should ideally also have IT specialists for the selected SCP software. One consultant mentioned that it was easier to find experts for prevalent tools (e.g. from SAP) than for applications from less known software vendors. In addition, it was explained that individual departments, in particular SCM, were responsible for the design of future SCP processes. Companies should assist software implementation with process knowledge. Key users would have to guide APS implementation regarding existing and desired SCP processes. Supply chain experts should take the lead for cross-functional optimisation and foster the link between individual planning tasks in the supply chain. Moreover, SCM staff should have basic knowledge of the applied statistical methods to understand the software output and to use the software effectively. A further requirement for APS adoption mentioned by the consultants was data quality. APS would process hundreds of parameters. Hence, data analysts had to ensure that master data were available and well maintained, otherwise software calculations could be faulty. One consultant also stated that companies required skilled procurement to specify the requirements and purchase the appropriate software in the end. It was elucidated that companies could also build up know-how internally to prepare for the software implementation, if the required expertise was not available in the organisation. Besides human resources, an organisation would further need to afford the time required for the implementation of a new software.

Leadership should also promote the change towards a new SCP tool. Change management was required to foster the acceptance inside an organisation to work with the new system. Supply chain managers had to realise that supply chain decisions were primarily driven by software tools. The interviews revealed that customisations in the ERP system would hamper the technical integration with SCP software. The more companies had maintained the software standard of the ERP system, the easier it was to set up interfaces with the new system. In addition, it was advised by the consultants that the implementation of APS was only economically viable, if companies had a certain size or supply chain complexity. One interviewee specified a minimum revenue of EUR 50 mil. Otherwise, there might be no positive business case for the introduction of SCP software. Moreover, it was indicated that company growth could lead to a faster ROI.

Table 5.11: Views of interviewed consultants on organisational requirements for APS implementation (based on author's own research).

Theme	Code	Sample statements
	Expertise	"Companies should define the desired business processes, and specify the

Organisational requirements for APS adoption		requirements for the new system accordingly.”
	Management support	“The management has to actively manage the change and show the benefits that are associated with the implementation of the new system.”
	Data quality	“The master data that are processed by the software need to be properly maintained. Otherwise, the results will be biased.”
	Company size	“If you expect strong business growth, then the investment will pay off faster.”
	SCM processes	“If planning processes are not implemented, nobody will say that software for SCP is needed.”

5.5.3 Drivers of APS Implementation

In the following section the views of the interviewed consultants on drivers of APS adoption are presented. Various software benefits were mentioned by the participants that would lead companies to implement APS (see Table 5.12). Demand planning software was adopted by companies to better predict the demand and increase the forecast accuracy compared to previous processes. According to the interviewees firms had realised that dedicated software was required to consider the data (e.g. weather, bank holidays) that had an impact on the demand. With forecasting software trends in consumer demand for certain articles could be recognised. Furthermore, companies could differentiate between regular demand and additional sales caused by promotions. As demand plans would serve as basis for subsequent planning processes, more accurate forecasts would also reduce overproduction and the associated food waste. According to the consultants APS for IP would be adopted by companies to get a better overview of inventory levels in different warehouses. Moreover, the calculation of parameters such as safety stock or reorder point as well as the automated update of such was another argument for companies to introduce a software for IP. Streamlined production processes and reduced planning effort were considered as main drivers for the adoption of software modules for production planning. Overall, enhanced service levels for customers, reduced waste and lessened planning effort were highlighted as drivers for APS adoption by the consultants. The consultants agreed that companies were induced to invest in an end-to-end solution to enable integrated planning across various departments and to overcome silo thinking in an organisation. It was appreciated by firms to have a “single point of information” that could reflect fluctuations in the supply chain and would thereby accelerate the company-wide alignment of planning processes.

Table 5.12: Views of interviewed consultants on drivers for APS implementation (based on author’s own research).

Theme	**Code**	**Sample statements**
Drivers for APS adoption	SC complexity	“The software tools are implemented to increase planning quality. Companies have realised that the systems can process data that humans cannot process.”
	Specific use cases	“Companies adopt APS to address specific planning challenges that cannot be solved by ERP systems.”
	Specific use cases	“By means of dedicated tools for SCP companies can analyse their standard and promotional sales separately.”
	Specific use cases	“Software for IP automatically calculates safety and reorder stocks. The parameters are updated over time.”
	Specific use cases	“Individual teams often follow different incentives. Companies adopt software tools to align their

		planning processes and achieve a better coordination across departments.”

5.5.4 Barriers to APS Implementation

The interviews with the consultants also revealed barriers to APS adoption (see Table 5.13). The costs were considered as major barrier for the implementation of SCP software. According to the interview participants many companies were reluctant to adopt APS due to the costs associated with an implementation project. Likewise, companies would often not view a business case that would justify the investment in a new software. It was argued that a business case was crucial to get the management support needed for an implementation project. This might be also caused by missing knowledge concerning APS within food companies. It was explained that several companies were not well informed about APS in general, and hence the added value for SCP processes was not recognised.

Another reason why organisations would decide against the implementation of software tools for SCP was the lack of expertise within the company. Many firms had neither the know-how to implement a software, nor the expertise to operate an APS. On that basis, decision-makers in the food industry were aware that an implementation project would not only require investment in the software, but also in human resources. The additional costs would discourage firms from software implementation. The interviews further revealed that companies lack the time for an implementation project. The key personnel required for a project were mostly not available due to the day-to-day business. Likewise, it was argued by one interview participant that managers had great respect for implementation projects. It was presumed that this was caused by news about failed IT projects in the media.

Different consultants shared the experience that food producers planned their supply chain by means of ERP systems instead of APS. It was indicated that ERP systems would also provide functionalities for SCP. Basic functionalities for SCP were sufficient for some food companies. Similarly, other firms would use data from the ERP system and execute the analyses for SCP in Excel spreadsheets. It was highlighted that a certain company size and supply chain complexity was required to generate a positive business case. Otherwise, specialised software was less necessary to support SCP tasks. Some firms would even not execute SCP processes at all, if the operations were too straightforward.

Furthermore, it was put forward that the staff in organisations was typically against change. Employees felt most comfortable with existing systems and hence would dislike the transition towards a new user interface. Therefore, companies would tend to maintain established SCP practices (e.g. via ERP systems, Excel) that are accepted by their employees. Apart from the key users, IT staff would also sometimes resist against new software, if the technical integration with the ERP system was perceived as troublesome. Moreover, the maintenance of additional software could trigger discomfort in the IT department.

Lastly, the consultants agreed that data quality of master data was inadequate in many firms. Initiatives to enhance data quality were attributed low priority. The limited data quality would inhibit companies in the food industry to implement software for SCP.

Table 5.13: Views of interviewed consultants on barriers to APS implementation (based on author's own research).

Theme	**Code**	**Sample statements**
Barriers to APS adoption	Lack of management support	"Many companies fear the high costs that are associated with software implementation projects."
	Lack of business case	"For many companies it is sufficient to plan the supply chain via the ERP system; you need a certain complexity so that it makes sense to invest in APS. The more complex the product, the more important it is to have an additional software for SCP."

	Lack of human resources	"Companies do not know that APS exist, especially medium-sized companies lack know-how regarding these software tools."
	Lack of data quality	"Master data quality is in 70 percent of all companies miserable. Projects for master data cleansing are not carried out."
	Complexity of interfaces	"Smaller companies often have specialised ERP systems. The creation of interfaces between such systems and APS is more complex."

5.5.5 Software Implementation Projects

The following section gives an overview of challenges in APS implementation projects observed by the interviewed consultants. In addition, advice how to facilitate these projects is provided (see Table 5.14).

The interviews with the consultants revealed different challenges that are frequently experienced by companies when APS are implemented. All interview participants stated that lack of availability of knowledgeable staff was a substantial impairment for software projects. Employees usually had to deal with their day-to-day business at the same time. Therefore, the experts in a firm often had only limited capacities for a software project. The technical integration with the ERP system was considered as another challenge. According to the interviewees IT departments typically claimed that the system standard of the ERP system was used, although companies had usually implemented multiple customisations in their ERP system. These could hamper the technical integration with APS modules. Furthermore, the mapping of company requirements was highlighted as crucial for every software implementation. The standard APS would rarely fit for a company. It was indicated that the requirements regarding company processes were often not known by the project team though. The interviews also revealed insufficient data quality as one reason for failure. The output of software tools for SCP would heavily depend on the data used as the input for these systems. Poor data quality could lead to inaccurate

SCP and biased decisions. This caused discontent of an organisation with the new SCP tool. In addition, some firms neglected change management as part of a software implementation project. If the staff was not convinced of the new systems, then a project would most likely fail.

Different measures were described by the consultants to address the aforementioned challenges and to facilitate APS implementation projects. It was pointed out that companies should create capacities of their employees. Organisations should ensure that capable staff is available for the project. Ideally these should be released from their day-to-day activities to focus on the project. It was argued that this would also reduce the overall costs of the project. Otherwise, the software vendor would have to take over more activities. Simple work in the project could also be carried out by interns or apprentices. It was advised that seasonal cycles of a business could additionally lead to shortages of staff in specific times. For example, a producer of soft drinks might lack personnel during summer. Different expertises were required for the implementation project of a new SCP system. Firstly, capable IT staff was needed. The IT department should know precisely about the existing IT infrastructure. An IT expert should guide the software provider where specific data could be retrieved from the ERP system. Secondly, data analysts should prepare master data prior to software adoption. These should ensure that the required data is available and well-maintained. Thirdly, process experts with an accurate overview of supply chain processes were required for the software implementation. In addition, key users from individual departments such as purchasing, controlling and sales should be involved in the project. Thereby, different teams could contribute their own ideas, and silo thinking was avoided. The key users should already be involved in the request for proposal (RFP) to ensure that the right system is selected. The project team and key users should specify requirements for the new system. The better the requirements were defined, the easier it was to find a suitable software. By means of an evaluation matrix various APS could be compared based on previously determined parameters. These included, amongst others, functionalities, usability, and the licensing model. The references of a software vendor should be queried as well as part of the tendering process. Additionally, it was useful to test the systems with real data of the company to get insights into the performance of such tools. The outcome (e.g. the forecast accuracy) could then be compared with the accuracy of current methods.

A software implementation project further required adequate project management. Unnecessary delays in the project timeline could be avoided by careful preparation of the project. A few things could be anticipated. Legal or administrative hurdles such as access to the company's IT system for external support were mentioned as examples in the interviews. It was recommended to take the time and plan the project together with the software vendor after the system had been selected. Besides the company, also the service provider should clearly assign resources to the project. It was emphasised by one consultant that the success of the customisation of the APS would depend on the process experts and the IT service provider. The former were supposed to specify the company's requirements and highlight these, while the latter should query the requirements properly and implement them well. Regarding the technical integration of the APS with the ERP system it could be helpful to approach the ERP provider for the set-up of the interfaces between the systems.

The interviews revealed an average project duration of six to twelve months for the implementation of a software module for SCP from market research to go live. It was indicated that it could take a few years before the system had surpassed the current planning quality and enhanced SCP processes as targeted. The consultants further agreed that change management was essential to introduce APS successfully in a company. It was argued that the new software solution ultimately had to be accepted by all users. Therefore, the staff should be involved and informed about benefits of the project, why a new system was needed and how their work will change. Short-term benefits should be highlighted towards stakeholders to maintain the enthusiasm for the project throughout this time. According to the interviewees the project should be continuously monitored using previously defined success indicators. These could be various KPIs (for forecast accuracy, availability, production costs, etc.) depending on the implemented software module.

Table 5.14: Views of interviewed consultants on how to facilitate APS implementation projects (based on author's own research).

Theme	Code	Sample statements
Implementation projects	Ensure availability of resources	"The people are not assigned to the project. They have to deal with the day-to-day business plus the implementation of the new software."
	Ensure availability of resources	"IT expertise regarding the existing IT landscape is required. You need to tell the software vendor where specific data is located."
	Ensure availability of resources	"You need employees who understand the IT system, in combination with someone who has an overview of the different areas of the supply chain."
	Highlight process requirements	"100 percent of the system standard rarely works. The success depends on how well the software customisations are implemented. Companies must point out certain process requirements and the IT service provider should implement these accordingly."
	Maintain management support	"The new tool needs to be accepted in the company. Therefore, change management is required. Employees should be involved and successes need to be highlighted."

5.6 Chapter Summary

The interviews revealed different requirements for APS adoption, drivers, and barriers to APS implementation. In addition, practical advice how to facilitate APS implementation was put forward. Multiple views of the practitioners from the food companies were confirmed in the interviews with the external experts. Various functionalities were mentioned by the interview participants as system requirements for APS adoption. It was emphasised that system requirements would highly depend on individual food sectors. The software vendors argued that these could be accommodated by specialised software templates. Moreover, the ease of use and the technical integration with the ERP system were highlighted as critical software requirements by the interviewees.

The interview participants also agreed on certain organisational requirements for APS adoption. It was indicated that different forms of expertise should be present in companies when APS is implemented. These included especially know-how regarding present IT infrastructure, data expertise, and process expertise. Additionally, existing SCP processes were considered as foundation for the implementation of the corresponding software modules to support these processes. Likewise, a firm's management should be committed to the introduction of the new software.

The interview results suggested supply chain complexity as major driver of APS adoption for food producers. Two food companies of the interviewed supply chain managers were induced to adopt APS as a consequence of an increased product portfolio.

Similarly, the interviews showed different barriers to APS implementation. It was mentioned that some food companies did not require SCP software due to a lack of supply chain complexity. Furthermore, the costs associated with APS implementation inhibited companies to adopt SCP software. Lack of expertise and time were considered as barriers to APS implementation as well. Insufficient data quality was another factor why companies decided against SCP software. Lastly, the interview participants agreed that companies would generally tend to avoid change. Employees would prefer to maintain existing ways of working and systems used.

The interview results showed different hints by software vendors and consultants how APS implementation can be facilitated. The lack of capacities of employees was considered as major challenge in software projects. Therefore, companies should free the relevant experts from their day-to-day work to enable them to focus on the project. These experts should highlight the requirements to customise the system properly. Companies should also put emphasis on data maintenance. Otherwise, the output of newly introduced decision support systems could be biased. In addition, employees should be aligned regarding expectations and benefits of the software. Change management was required to motivate employees to work with the new system. The development of a strategic roadmap could help companies to drive the transformation of SCP processes in a targeted manner. The number of times certain codes appeared was neglected as not all codes were considered as equally significant. The frequency of codes in the interview responses can still be found in Appendix 11.

In the next chapter, the interview results are discussed together with the survey outcome. An adapted TAM is introduced that explains APS implementation based on the employed mixed methods research design.

6 Discussion and Development of APS Adoption Model

6.1 Introduction

The management of food supply chains is complex. APS can support supply chain practitioners in this industry to retain an overview of the supply chain. Previous literature indicates that the adoption of specialised software for SCP is limited though (Jonsson and Ivert 2015; Vlckova and Patak 2011). Considering the potential benefits of decision support tools for SCP, a better understanding of APS adoption is needed. A survey among managers of food producers was thus conducted to create an overview of APS adoption in the food industry. Subsequently, leaders of food producers, software vendors and consultants were interviewed to explore requirements, drivers and barriers to APS implementation. Likewise, practical advice to facilitate software implementation was queried. In this chapter the findings of the quantitative and the qualitative study are jointly discussed. The research findings were used to refine the propositions regarding antecedents of APS adoption from Chapter 2. The APS adoption model is introduced that explains APS implementation by companies based on the findings of this mixed methods research.

6.2 Discussion of Survey and Interview Results

In this section the survey and interview results are discussed. Firstly, the research outcome regarding the use of SCP software in the food industry is interpreted and compared with existing literature. Secondly, organisational and system requirements for APS implementation as well as drivers and barriers to APS adoption are discussed. Thirdly, insights on how to improve APS implementation are reflected together with previous research.

6.2.1 APS Adoption in the Food Industry

The survey results provided evidence that APS modules are implemented to a limited extent in the food industry. Most survey participants indicated the use of SCP software for PP&S (42%). 38% of the firms employed software to support IP and 36%

of the participating companies performed S&OP by means of software tools. Only 4% of the companies used software to assist strategic decisions (SCND). Likewise, the outcome showed that 36% of the firms planned to implement S&OP software within the next two years, while 30% indicated the intention to adopt software for PP&S in that timeline. The results further revealed that multiple food companies did not plan to adopt APS. A large part of the surveyed managers (79%) stated that the implementation of software for SCND was not planned. The survey outcome showed that sophisticated software solutions for SCP were used by only a few food companies. 24% of the food producers indicated APS modules as leading planning system. 38% of the firms used ERP systems for SCP. Moreover, 22% of the participants performed SCP activities by means of SCE systems. 16% of the food companies employed generic tools such as Excel for SCP.

Basic methods to optimise business operations (e.g. inventory models to optimise inventory levels) can be executed via spreadsheets as well (Shang et al. 2008). ERP systems can also include functions for SCP. APS incorporate more sophisticated functionalities to support SCP though. In contrast to ERP systems, APS provide a higher level of detail, simulation features and interdependencies of different constraints are captured in a better way to optimise plans (e.g. production schedules) accordingly (Setia et al. 2008). The low adoption of software tools for SCND may be attributed to lack of knowledge regarding these systems as indicated by many participants. Overall, the results of this research correspond to the findings of previous studies regarding the use of sophisticated software for SCP (Vlckova and Patak 2011; Jonsson and Ivert 2015). Furthermore, the research provides evidence for the gap between research and practice in the domain of SCP identified by Jonsson and Holmström (2016). The outcome suggests that the efforts on the development of sophisticated models for SCP from the past years were hardly valued in practice.

The independent samples t-test yielded a possible explanation for the low adoption of sophisticated SCP software. The comparison of different supply chain characteristics between users and non-users of APS revealed that companies that had implemented specialised software were larger in size. Significant differences between both groups in terms of revenue and number of employees were identified. According to the test statistics firms using software for S&OP (p-value < 0.01) and IP (p-value < 0.01) had significantly higher revenues. Similarly, food companies that employed APS modules had significantly more employees, i.e. IP (p-value < 0.05) and S&OP (p-value < 0.1). Thus, constrained resources can be inferred as major impediment to implement APS for smaller companies. Former research proved that SMEs have difficulties to adopt supply chain technologies due to limited financial resources (Masood and Sonntag 2020). Furthermore, a lack of human resources (e.g. experienced staff to implement and operate the systems) may inhibit smaller firms to adopt SCP software (Verma and Chaurasia 2019; Arunachalam et al. 2018). Firms using S&OP software had also a larger product portfolio (p-value < 0.05).

In addition, companies that employed SCP software indicated a lower supply uncertainty compared to firms without APS, i.e. S&OP (p-value < 0.01), IP (p-value < 0.05) and PP&S (p-value < 0.05). Food companies with SCP software further tended to have a lower production uncertainty, i.e. PP&S (p-value < 0.05) and IP (p-value < 0.1). The results suggested that supply chains of firms using APS were characterised by lower levels of complexity. This inference is inconsistent with previous research. Tenhiälä (2011) argued that planning methods should be aligned with the complexity of business processes. It was further claimed that more sophisticated technology does not necessarily lead to better results. SCP systems should be selected based on organisational characteristics and the complexity of planning tasks (Tenhiälä 2011; Setia et al. 2008). Following the argumentation of the authors, the supply chains of companies that have implemented APS modules should be attributed a higher supply chain complexity. There is consensus among academics that the management of food supply chains is challenging (Trienekens et al. 2012; Akkerman et al. 2010). As a result of using SCP software, the perceived supply uncertainty and production uncertainty might be reduced. A similar outcome was determined in an earlier study. The authors found that the negative impact of planning environment complexity could be reduced by sophisticated methods of SCP (Jonsson and Ivert 2015). Likewise, firms without APS might perceive the supply chain as more complex.

Furthermore, the survey outcome revealed that most functions of APS modules were considered as very useful by practitioners. This corresponds to the advantages of APS documented in the literature (Mickein et al. 2022; Jonsson et al. 2007). A similar positive outcome with respect to the benefits of Industry 4.0 technologies was found in past survey research (Masood and Sonntag 2020). It was noted that survey participants tend to assess future technologies as more useful. The results of this survey could be similarly affected. Only the functionalities of software for SCND were rated as rather moderately useful. This could be explained by the lack of prior knowledge among survey participants regarding decision support tools for SCND. Companies with high production uncertainty indicated a higher usefulness of APS for PP&S (p-value < 0.01), IP (p-value < 0.05) and SCND (p-value < 0.1). Similarly, higher usefulness of software functions for S&OP was reported by larger organisations in terms of revenue (p-value < 0.05) and number of employees (p-value < 0.1). Surveyed firms with an average product shelf life of up to 30 days found the system functions for S&OP (p-value < 0.1) and IP (p-value < 0.1) less useful. Software tools could thus be less effective to deal with short product shelf lives.

6.2.2 Considerations affecting APS Adoption

The research revealed different factors that might affect the decision of companies to invest in APS. In this section, system and organisational requirements for APS implementation are discussed. Additionally, drivers and barriers to APS adoption are compared with previous literature. Although the findings are primarily based on interviews with managers from food producers and experts on APS implementation in the food industry, the results may also be relevant for other industries.

System requirements for APS implementation

It was highlighted in the interviews that companies demand different software functions from APS vendors. These are company-specific and typically detailed in the specifications. Various functions of APS modules can be found in the literature (Lütke Entrup 2005; Setia et al. 2008; Stadtler et al. 2015). For instance, APS can provide what-if analyses to evaluate effects regarding supply problems of raw materials, or changes in consumer demand. Likewise, automated production schedules can be created by SCP software (Setia et al. 2008). Interdependencies of planning decisions can be captured by APS which contributes to increased flexibility (Stadtler et al. 2015). Requirements of companies also depend on individual industries. Most food companies follow a pull method for production planning, whereas some food sectors (e.g. diary and meat industry) require combined pull and push approaches. The consideration of external factors such as weather data or special football events in demand planning software is an important requirement for the brewing industry. Different case studies revealed the benefits of APS (reduced inventory levels, greater planning accuracy, integrated planning, etc.) (Jonsson et al. 2007; Zago and Mesquita 2015; Mickein et al. 2022; Rudberg and Thulin 2009). It was emphasised by the interviewed participants that company-specific processes (e.g. production processes) needed to be mapped in the system to achieve these benefits.

Furthermore, the usability of SCP software was highlighted across all groups of the interviewed experts as an important requirement. This includes a modern, well-structured and comprehensive user interface that covers all key aspects such as KPIs for decision-making. The latter may differ depending on the needs of a company. The software tools should systematically guide users for an intuitive usage. The usability of the software is often examined in workshops with software vendors and was viewed as a decisive factor for the final software selection within the tendering process. This result is in line with existing literature. As an integral part of different TAMs the ease of use of IT systems was confirmed in various studies as determinant of technology adoption (Davis et al. 1989; Venkatesh and Davis 2000; Venkatesh et al. 2003; Verma and Chaurasia 2019). Overall, ease of use and different software functionalities were considered as most significant system requirements of companies towards software firms. This was also reflected in the statement by an interview participant who explained that the rationale of the software project was to reduce the time spent on SCP activities, while the quality of the plans should be enhanced. Thereby, the software should provide added value.

Another aspect stressed by most interviewees was the integration of the APS with the existing IT landscape, in particular with the ERP system. The calculations of APS are usually based on data from the ERP system. Although the interviewed software firms assured that their systems could be integrated with any ERP system, it was acknowledged that this was a challenging task in some cases. A company may even require the integration of APS with different ERP systems from various software providers as one interview revealed. The integration of APS and ERP systems was also described in previous research (Wiers 2002).

Customer support and data security were less frequently mentioned as requirements towards the software firms. Both topics should not be neglected by software vendors though. Many companies are still inexperienced in terms of APS. In addition, concerns regarding the privacy and security of data are revealed in the literature (Arunachalam et al. 2018; Ivert and Jonsson 2011).

Organisational requirements for APS implementation

Likewise, this research uncovered different requirements for companies that should be considered when the implementation of SCP software is intended. The interviews showed that firms require competent staff for the implementation of APS as suggested in previous research (Zago and Mesquita 2015; Ivert and Jonsson 2011). Experts from different areas are needed for the introduction of SCP software. In particular, IT and process expertise should be provided by firms. Firms may have to take responsibility for the integration of the new system with the IT landscape (e.g. set-up of interfaces). In addition, data analysts and staff with project management competencies are advantageous. In contrast to ERP implementation projects, project teams for the introduction of APS are rather small as indicated by Wiers (2002). It is further useful, if companies have already personnel with knowledge how to operate the new software. According to the interviewed experts many firms lacked staff with experience how to operate specialised SCP software. The staff needed to accept that the planning is performed by the software. This is in line with the call by Arunachalam et al. (2018) for a data-driven culture in companies to reap the benefits of BDA technologies. There is evidence that adjustments by users lead to rather detrimental results (Khosrowabadi et al. 2022; Setia et al. 2008).

The survey and interview results suggested that APS implementations require a certain company size. Different reference values were advised by the interviewed experts. Otherwise, it may not be worthwhile to implement APS. Two reasons became evident for that. Firstly, organisations require the budget to finance the software and the associated implementation project including required consulting services. Software firms usually charge an annual fee for cloud solutions. Companies might have to pay additional licensing fees and maintenance fees. Previous studies confirm that SMEs are constrained to adopt new technologies due to limited financial resources (Masood and Sonntag 2020). Secondly, the research indicated that firms with simpler planning processes may not require specialised software to optimise SCP. Smaller organisations tend to have less complex business operations. This result corresponds to the findings of earlier research that advocated a fit between the use of SCP software and supply chain characteristics (Setia et al. 2008; Tenhiälä 2011).

Another requirement for the introduction of APS that was highlighted in this study is data quality. Master data should be properly maintained. High data quality was considered as prerequisite by the software vendors. If the data was not maintained, the output of the decision support tools would be biased. It was argued that data quality in most firms was poor. The significance of data quality for data analytics to enhance supply chain processes was also emphasised by Hazen et al. (2014).

Moreover, the support of top management is highly important for the implementation of APS. The management should be committed to a project and provide full support. Yet, it was clarified during the interviews that the resources for a project would not be unlocked, if the management was not convinced of a positive business case. The impact of top management support on the adoption of BDA was also confirmed in previous empirical studies (Verma and Chaurasia 2019; Lai et al. 2018).

APS contribute to enhanced collaboration across functions (Jonsson et al. 2007). According to the interviewees business processes would need to be defined prior to the implementation of SCP software. These should be linked to the requirements for the new system correspondingly. The digitalisation of immature processes is inefficient and leads to failed IT projects (Clause and Simchi-Levi 2005).

The interviews revealed that smaller companies tend to have more specialised ERP systems which can impede the integration with the new software. The difficulty of the technical integration of both systems can be reinforced by customisations of the ERP system.

Drivers of APS implementation

Different drivers of APS adoption were determined in this research. Two of the interviewed managers of food companies indicated that the firms were planning to adopt APS modules as a consequence of increased supply chain complexity. This was mainly caused by an increased product portfolio. The sausage manufacturer started to additionally produce veggie products. The liquor producer was acquired by a multinational beverage group and the company began to also sell the products from other firms in the beverage group. Setia et al. (2008) determined in their case studies a similar pattern. One of the two firms had to adopt APS to maintain service levels in a dynamic industry environment with changing customer demand. The other company had to cease spreadsheet-based planning and adopt SCP software to be able to deal with increased production complexity. The interviewed experts confirmed that most companies start managing their supply chains based on spreadsheets. Once it was realised that planning activities are too time-consuming and the results do not lead to the desired quality, companies would consider the investment in specialised tools. This was particularly observed in the food industry where firms need to take multiple parameters for SCP into account.

Furthermore, company-specific use cases induce firms to adopt APS modules. These use cases include increased material availability, enhanced reliability to the customer or reduced food waste. The implementation of software is also viewed as enabler to achieve company goals (Grimson and Pyke 2007; Setia et al. 2008). Companies demand specialised software that are targeted for their individual goals. Previous studies identified perceived benefits and relative advantage as determinants of adoption intention in the context of BDA (Verma and Chaurasia 2019; Lai et al. 2018). Benefits that can be achieved by APS implementation were revealed in various case studies (Zago and Mesquita 2015; Rudberg and Thulin 2009; Jonsson et al. 2007).

Additional factors mentioned in the interviews that may cause APS adoption were considered as less significant for the final decision to invest in SCP software. The review of SCM practices can trigger companies to reflect existing business processes. This could be prompted by projects with external consultants or new management that joined a company. In addition, enhanced job attractiveness for supply chain planners may be regarded as additional benefit of sophisticated SCP systems, but not as motive for software implementation. Firms can also be induced to implement APS modules through the adoption of a new ERP system. The software vendor may provide additional software to support SCP. This was also found by Ivert and Jonsson (2011) in a case study of a brewery company.

Barriers to APS implementation

A low expected ROI as well as lack of time and expertise were determined as major barriers to APS adoption based on the survey outcome. The results were confirmed in the qualitative study of this research. The introduction of SCP software does not constitute a promising business case for certain companies. This can be due to multiple reasons. Many firms lack the required financial resources for the software and the associated implementation project. External consulting services can increase the necessary budget. For other companies the use of sophisticated technology for SCP is not needed, because their business processes are rather simple. Spreadsheet-based SCP or holistic ERP systems with basic functions for SCP can be sufficient as discussed in previous studies (Setia et al. 2008; Tenhiälä 2011). In addition, the ROI of software implementations is usually difficult to calculate. An unclear ROI was also determined as impediment for big data implementation in other research (Richey Jr et al. 2016).

Another barrier that prevents firms to adopt specialised tools for SCP is the lack of human resources. This can be manifested in different forms. Firstly, many firms do not have the time for a project that would be required for the introduction of a new software. Secondly, company leaders are aware about the lack of expertise in the organisation to operate a new software, but also for the implementation of APS (including the technical integration with existing IT infrastructure). Both aspects were already reflected in the survey results. Thirdly, the research revealed that there may be also lack of know-how among decision-makers. It was indicated that some executives were not aware of sophisticated software for SCP, and hence alternative ways to perform SCP activities. The need for skilled staff to benefit from BDA was already postulated by different scholars (Arunachalam et al. 2018; Schoenherr and Speier-Pero 2015; Richey Jr et al. 2016). The hypothesised impact of capabilities on the intention to adopt BDA was not supported in the study by Lai et al. (2018). Other research found that limited knowledge among SMEs impedes the implementation of Industry 4.0 technologies (Masood and Sonntag 2020).

The results of this research are further in line with previous studies regarding the impact of top management support on technology adoption (Verma and Chaurasia 2019; Lai et al. 2018; Jeyaraj et al. 2006). It was highlighted during the interviews that SCP software would not be implemented, if the management was not convinced of the benefits. Moreover, it was suggested that the significance of integrated planning across departments was underestimated by managers.

Lack of data quality was put forward as a barrier to APS adoption as well. Overall, different previously outlined organisational requirements (e.g. company size, expertise) for APS adoption were also considered as impediments for the implementation of SCP software. The outcome lends support for the notion that the belief of decision-makers in the organisational capabilities has an essential impact on the decision to adopt SCP software.

6.2.3 APS Implementation beyond Adoption

IT system implementations can fail (Venkatesh and Bala 2008; Clause and Simchi-Levi 2005). Similarly, the adoption of APS does not necessarily lead to the promised benefits (Günther 2005; Setia et al. 2008). The survey outcome showed that the companies that had implemented SCP software were largely satisfied with the performance and the associated benefits of the adopted systems. It was indicated by some firms that implementation projects took longer, and costs were higher than expected. A delayed project schedule was also determined by Zago and Mesquita (2015) in a case study of an S&OP implementation. In the qualitative study of this research different suggestions, how implementation projects beyond software adoption can be enhanced, were shared by the interviewed experts. These are discussed in the following section.

1) *Ensure availability of project team*

Firstly, companies need to ensure to provide capable staff for the software project. Project teams for the introduction of SCP software are usually smaller than for ERP system implementations (Wiers 2002). Different competencies should be present in the project team. The personnel required usually include process experts (e.g. demand planner, supply planner), IT experts and project managers. Team members should be clearly assigned to the project (Ivert and Jonsson 2011). Required experts were often involved in different projects. It was highlighted in the research that the project team should ideally be freed from day-to-day operations to be able to fully concentrate on the software project.

2) *Maintain management support*

APS modules are only adopted, if the software implementation is approved by the firm's management. This includes the contribution of financial and human resources needed for the project. Management support for a new system should not only persist for the decision to invest into a new software. The management should rather be committed to the new system throughout the entire project and drive the change in the organisation. Stakeholders should be aligned regarding expectations and purpose of the software. The staff should have a proper understanding why a new software was introduced. If the personnel do not recognise the added value of a new system, project members might be less motivated to contribute to the project or may even drop out (Ivert and Jonsson 2011). Lack of commitment may even delay the project schedule (Zago and Mesquita 2015). The interviews revealed that the full potential of new SCP software can mostly be generated after years. Hence, accomplishments should be shared to maintain support for the new system among stakeholders. Management support can foster the assimilation of new technologies within organisations after technology adoption (Gunasekaran et al. 2017). Likewise, the positive impact of management commitment to IT projects on implementation success was confirmed in earlier research (Wamba et al. 2015). Furthermore, the implementation of APS should not lose management priority in case of other parallel IT projects (Ivert and Jonsson 2011).

3) Highlight process requirements

Another important aspect in APS implementation projects is the customisation of the system according to the customers' needs. It was emphasised by the interviewed experts that requirements need to be highlighted by companies. Therefore, process experts were required to actively address requirements and guide software firms regarding system customisation. Both previous factors can be considered as a prerequisite for this. Capable process experts should be part of the project team. Additionally, the staff should be willing to support the customisation of the decision support tool (Zago and Mesquita 2015). APS modules may provide biased output, if requirements are not highlighted during the system setup (Ivert and Jonsson 2011). This could again easily lead to dissatisfaction among stakeholders with the newly introduced software.

4) Ensure high data quality

The significance of data quality for SCM is corroborated by multiple literature (Hazen et al. 2014; Arunachalam et al. 2018). Decision-making in SCM is increasingly based on big data. Hazen et al. (2014) appealed to leaders to prioritise data management accordingly. Companies should actively monitor and control the quality of their data. Arunachalam et al. (2018) encouraged firms to develop a data driven-culture. This requires companies to take precautions and ensure high data quality. The importance of data quality was similarly emphasised in the qualitative study of this research. The software vendors highlighted well maintained data as prerequisite for the introduction of SCP software. In addition, companies need to support software firms to gather the data from the ERP system in order to subsequently validate the model incorporated in the APS module (Ivert and Jonsson 2011). Poor data quality can lead to biased system output and may delay the adoption of decision support tools by users as a consequence (Setia et al. 2008).

5) *Develop strategic view for targeted software adoption*

This research suggests that firms should strategically reflect SCP practices together with their goals. Companies have different options to plan the supply chain. Firms can use generic tools such as Excel, ERP systems or sophisticated software for SCP. Spreadsheet-based planning can be sufficient for some companies. Supply chain planners in certain firms may require basic functionalities of ERP systems to coordinate the goods along the supply chain. In other companies sophisticated software is needed to fulfil SCP tasks. The decision to invest in technology to support SCP should be aligned with the corporate strategy and the complexity of supply chain processes. This is in line with previous research (Setia et al. 2008; Tenhiälä 2011). If processes are less complex, managers may not require sophisticated tools to plan the supply chain. Although the selection of adequate software to support SCP is made prior to the project, the fit between the technology and supply chain processes may significantly impact the prospects of success of software implementation. Moreover, organisational capabilities required for sophisticated methods of SCP should be reviewed. The implementation of SCP software is facilitated, if organisational prerequisites to operate APS (experienced staff, high data quality, etc.) are met (Setia et al. 2008).

Overall, the adoption of APS does not automatically translate into the expected benefits. Based on existing literature and the insights gathered in this research different practical advice to facilitate APS implementation was given. Companies might increase the likelihood to successfully implement SCP software by considering the previously mentioned aspects.

6.3 APS Adoption Model

This research aims to better understand APS adoption of companies. The TAM by Davis et al. (1989) is a widely acknowledged framework to understand the adoption of IT systems. PU and PEOU constitute key predictors of technology adoption in the model. Both constructs have been repeatedly confirmed as determinants of technology adoption in the literature (Lai 2017; Taherdoost 2018). Technology adoption models should not be simply applied across technologies. Characteristics of technologies and organisations should be taken into account when adoption behaviour is studied (Treiblmaier 2019). The adoption of various technologies has been examined in the past based on the TAM. In some studies the models were extended to better capture the adoption of different technologies (Amoako-Gyampah and Salam 2004; Gao and Bai 2014; Lee 2009). In this section an adapted TAM for the context of APS, the APS adoption model, is presented.

The APS adoption model was developed based on the mixed methods research (see Figure 6.1) and provides explanations for the introduction of SCP software by companies. In particular, antecedents of PU and PEOU in terms of SCP software were explored to get a better understanding of APS adoption. This might answer the question what makes APS modules useful or easy to use. Different factors could be identified that may affect the decision to adopt APS. Most of them were incorporated as antecedents of PU and PEOU in the model. The antecedents of PU and PEOU are distinguished between company characteristics and system characteristics. Both were also determined as significant predictors of IT adoption by organisations in previous research (Jeyaraj et al. 2006). In addition, the model shows how PU and PEOU affect the decision to introduce APS. The initial model presented in Chapter 2 (see Figure 2.5) was thus adjusted following the outcome of the quantitative and qualitative studies.

In the next sections different research propositions are stated based on the APS adoption model. Firstly, company characteristics affecting PU and PEOU are proposed. Secondly, system characteristics affecting PU and PEOU are explained. Thirdly, it is outlined how PU and PEOU are expected to affect APS adoption in organisations. Lastly, it is described how the model could be validated.

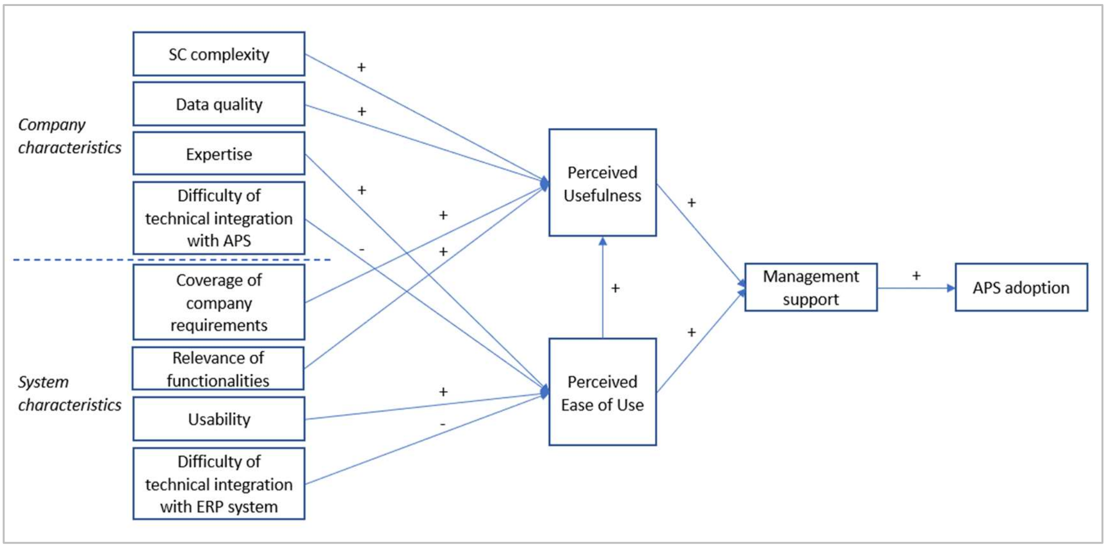

Figure 6.1: APS adoption model (adapted by the author from Davis et al. (1989)).

6.3.1 Company Characteristics affecting PU and PEOU

In this mixed methods research different company characteristics were identified that might impact PU or PEOU of APS modules. These include SC complexity, data quality, expertise, and the difficulty of the technical integration with SCP software. Various research propositions are stated in the following section.

The survey results showed that APS are more frequently implemented in larger companies. Smaller firms may not need to adopt SCP software because of less complex business processes. The qualitative study of this research revealed that firms usually start with less sophisticated methods of SCP. Two interviewed managers from food producers indicated the implementation of APS modules as a consequence of an enlarged product portfolio. Both firms were required to adopt SCP software to maintain the ability to effectively manage the products along the supply chain. It was confirmed by other interview participants that in certain companies it was hardly possible to perform planning tasks without specialised software due to the multitude of parameters to be considered. The following relationship is proposed based on the findings:

Proposition 1: Increased supply chain complexity is expected to have a positive impact on the PU of software tools for SCP.

The research further showed that companies should have well maintained data to benefit from the output of the decision support tools. Poor data quality could lead to biased results of APS modules. Low data quality was stated by one interviewee amongst other factors as reason against the adoption of SCP software. The results suggest that companies have an idea of the level of data quality. In addition, it was argued that companies usually test the software models with company data as part of the tendering process. Impracticable plans caused by low data quality might not support supply chain planners to effectively perform their tasks. Therefore, the following proposition is stated:

Proposition 2: Greater data quality is expected to have a positive impact on the PU of software tools for SCP.

Companies require different competencies to support the introduction of APS. Firms should ideally provide IT and process experts for the software implementation. Data analysts and project managers can further reduce the dependency on external consulting services. Furthermore, staff with experience how to operate the APS module can facilitate the introduction of the new system. The results of this research reveal that competent staff in companies lack capacities to support additional projects. Experienced staff is often already involved in several other projects. Skilled personnel are limited in smaller firms in particular. If there is lack of expertise to support the software implementation and to use the system, companies rely more on external know-how. Additionally, more training is required to assimilate the skills needed to operate SCP software. The following proposition is stated:

Proposition 3: Greater expertise within an organisation is expected to have a positive impact on the PEOU of software tools for SCP.

SCP software mostly rely on data from ERP systems. The integration of both systems usually constitutes an essential part of implementation projects. It was reported by one manager that the SCP software had to be integrated with different ERP systems from the beverage group. The interviewees noted that the integration of the firm's IT landscape with APS modules can be challenging, if the ERP system is heavily customised. Hence, more effort was required to integrate the APS module into the IT landscape. The following proposition is supported accordingly:

Proposition 4: Increased difficulty of the technical integration with the SCP software is expected to have a negative impact on the PEOU of software tools for SCP.

6.3.2 System Characteristics affecting PU and PEOU

The research uncovered different characteristics of APS that might impact PU or PEOU of APS modules. These include coverage of company requirements, relevance of functionalities, usability, and the difficulty of the technical integration with the ERP system. Several research propositions are stated in the following section.

It was highlighted in the qualitative study that APS modules usually require customisation according to supply chain characteristics. For instance, the planning board of software for production planning in dairy companies should cover the different production stages from the delivery of milk through pasteurisation, blending processes etc. Additionally, companies follow different supply chain strategies. While certain firms coordinate goods based on a pull system along the supply chain, other firms operate their supply chains through push strategies or combined approaches. Some software firms provide individual software templates for distinct industries (meat, dairy, etc.) to match supply chain specifics. It can be argued that supply chain planners are enabled to perform tasks more effectively, the more company-specific requirements are fulfilled by APS modules. The following relationship is thus expected:

Proposition 5: Greater coverage of company requirements is expected to have a positive impact on the PU of software tools for SCP.

APS modules include different functionalities for SCP. For instance, software for SCND can support supply chain leaders to determine number and location of warehouses. S&OP software provide automated plans in case of bottlenecks along the supply chain. IP systems cover various functions for inventory optimisation and software for PP&S can generate automated production schedules. It was explained in the interviews that SCP systems and the incorporated functions are demanded by companies to support their individual goals. These could be increased material availability, enhanced reliability to the customer or reduced food waste. The integrated functionalities in APS modules that are more pertinent to achieve such goals might also support supply chain planners to perform their tasks more effectively. Therefore, the following proposition is stated:

Proposition 6: Greater relevance of software functions for the business is expected to have a positive impact on the PU of software tools for SCP.

Usability was emphasised as an important requirement for APS modules in this research. Software usability is for many firms the decisive factor for final system selection in tendering processes. The user interface of SCP software should be well-structured and cover all critical aspects to support decision-making. User-friendly systems contribute to a more convenient usage. In addition, supply chain managers spend less time on the actual creation of plans for the supply chain. Intuitive SCP software might further enable supply chain planners to faster assimilate the skills needed to operate the system. Hence, the following proposition is supported:

Proposition 7: Greater usability of SCP software is expected to have a positive impact on the PEOU of software tools for SCP.

As outlined before, APS modules usually need to be integrated with a firm's IT landscape. Data for APS are mostly gathered from ERP systems. Hence, APS modules should be capable to be interfaced with ERP systems as well. This was assured by the interviewed software vendors. Yet, it was conceded that the integration of APS modules with ERP systems can be complex in certain cases. The following proposition is stated accordingly:

Proposition 8: Increased difficulty of the technical integration with the ERP system is expected to have a negative impact on the PEOU of software tools for SCP.

6.3.3 Additional Propositions

This research did not only reveal insights regarding antecedents of PU and PEOU, but also how both variables might affect the decision to adopt APS in organisations. In the following section different research propositions are stated.

Previous studies found a significant impact of PEOU on PU (Amoako-Gyampah and Salam 2004; Gao and Bai 2014; Lee 2009). The interview results suggested this relationship also for the context of APS. The ease of use of SCP software was regarded as significant by the interviewed experts. It was argued by one interviewee that the new software was considered as useful, if the accuracy of SCP is enhanced and the time invested in spreadsheet-based planning could be minimised. SCM staff in many firms is inexperienced regarding sophisticated SCP systems. If APS lead to higher planning accuracy and likewise intuitively guide decision-making of SCM staff, supply chain planners will be enabled to perform their tasks more effectively. The following proposition is stated accordingly:

Proposition 9: Enhanced PEOU of software tools for SCP is expected to have a positive impact on the PU of software tools for SCP.

PU and PEOU are well acknowledged determinants of technology adoption in the literature (Lai 2017; Taherdoost 2018). This research suggests that investment decisions regarding APS are similarly affected by PU and PEOU. If management is convinced that supply chain planners can fulfil their tasks more effectively by means of APS and the systems are convenient to use, the implementation of SCP software might be advocated accordingly. Therefore, the following relationships are supported:

Proposition 10: Enhanced PU of software tools for SCP practices is expected to have a positive impact on management support for new software.

Proposition 11: Enhanced PEOU of software tools for SCP practices is expected to have a positive impact on management support for new software.

The decision to adopt new software is usually met by company leaders (Jeyaraj et al. 2006). The interview findings corroborated that management support is a significant requirement for APS adoption in organisations. Firms need to finance the software, but also the associated implementation project. The required resources for the introduction of SCP software have to be committed by decision-makers. Hence, the following proposition is stated:

Proposition 12: Greater management support for the use of software tools for SCP practices is expected to have a positive impact on the adoption of these systems.

6.3.4 Model Validation

In the previous sections the APS adoption model was presented. In this section the approach how the model could be validated is outlined. The APS adoption model reveals different antecedents of PU and PEOU in terms of SCP software, and likewise depicts how both constructs affect the adoption of SCP software in organisations.

The model was iteratively discussed and refined with the supervisors. Subsequently, the final draft was validated by five interviewees from the qualitative study of this research. The interview participants were asked via mail to provide feedback on the model. The model including a description was attached to the mail. Individual participants from each group of experts commented on the model. Feedback was received from one manager of a food company, one manager of a software vendor, and three consultants.

The feedback provided by the managers was predominantly positive. All respondents stated that the results would be in line with expectations or that the proposed relationships could be confirmed. The significance of supply chain complexity was reinforced in some feedback. Companies would only invest in sophisticated software, if there was high pressure to act. Firms with less complex supply chains would conduct SCP rather by means of spreadsheets or basic functions of ERP systems. Additionally, the usability of APS was highlighted again as essential for companies. Another manager noted that usability and the technical integration of APS with ERP systems were rather requirements, and less motives for the introduction of SCP software. This does not contradict the rationale of the model. The determined factors affecting the adoption of sophisticated software for SCP including requirements, drivers and barriers to APS implementation were summarised and mainly integrated as antecedents of PU and PEOU in this model. If the technical integration of APS with ERP systems was complex, the PEOU is expected to be lower. This might negatively impact the likelihood of APS implementation in an organisation. One manager provided feedback that the business case was a decisive factor whether companies decide for or against the introduction of sophisticated software for SCP. The business case was not incorporated in the APS adoption model. It can be argued that a positive business case coincides with high PU and PEOU. The mathematical calculation of the commercial benefit of investments in APS is neglected in this research and can be addressed in future studies. This research was rather focused to generate a better understanding of APS adoption.

Overall, the APS adoption model could be validated based on the feedback from the experts. It can be concluded that the model adequately reflects technology adoption behaviour of companies in terms of APS.

6.4 Chapter Summary

In this chapter the outcome of the mixed methods research was discussed. At first the results regarding APS adoption in the food industry were reflected. The survey results correspond to earlier studies that indicated a low implementation of APS by companies. Sophisticated approaches for SCP that have been developed in past research are only implemented to a small extent in the food industry. Larger companies tend to adopt APS modules more often. This could be due to higher availability of human and financial resources. Generic tools such as Excel or basic functions in ERP systems are used by many food companies for SCP. Technological support for SCP practices might be selected based on the complexity of supply chain processes. The main findings regarding system and organisational requirements were analysed in conjunction with previous research. In addition, drivers and barriers to APS adoption were discussed. Five recommendations to enhance APS implementation revealed in the qualitative study of this research were further outlined.

Based on this research and existing literature the APS adoption model was introduced. The model is an extended version of the TAM for the context of SCP software and incorporates different factors affecting APS adoption identified in this research. Most of them are included as antecedents of PU and PEOU of SCP software. The antecedents are differentiated between company and system characteristics. PU and PEOU are expected to affect top management support regarding the adoption of APS. The model should provide a better understanding of APS adoption by companies. Twelve research propositions were derived from the model. These can be investigated in future research. The APS adoption model was validated by different experts. Thus, it is considered as an adequate depiction of APS implementation by companies in practice.

7 Conclusions

7.1 Introduction

In this chapter the mixed methods research is concluded. Firstly, the research findings regarding the three research questions are summarised. Subsequently, implications of this research for academics and practitioners are outlined. Lastly, limitations of this research and suggestions for future research are put forward.

7.2 Summary of Research

Supply chain managers in food companies need to consider different characteristics of food products (e.g. shelf lives, cooling requirements). Changing consumer behaviour and global supply chain disruptions amplify the complexity of SCM in the food industry. SCP is fundamental for food companies to coordinate the demand with the supply of products. APS modules incorporate mathematical models to optimise SCP and support decision-making in companies. The systematic literature review revealed that multiple sophisticated models have been developed and customised to complex planning problems within food supply chains. Empirical evidence regarding the implementation of the modelling approaches in practice is limited though. Likewise, a lack of research in terms of technology adoption of APS was determined. The aim of this research was thus to develop a better understanding of the technology adoption behaviour of food companies in terms of APS. The research aim can be broken down into three research objectives. Firstly, this research intended to establish an overview of APS implementation in the food industry. In addition, the research aimed to identify antecedents of PU and PEOU regarding SCP software. Both constructs are well acknowledged determinants of technology adoption. Another objective was to determine how the implementation of APS beyond software adoption can be facilitated.

To achieve the research objectives a mixed methods research approach was applied. This comprised a quantitative survey followed by qualitative interviews. Mixed methods research draws on strengths of quantitative and qualitative methods and limits weaknesses of separate quantitative or qualitative studies. The survey allowed to gather data regarding APS implementation from multiple food companies across different regions. The interviews were useful to add meaning to the survey results and to generate a more in-depth understanding of APS adoption by companies. The quantitative and qualitative method thus complemented each other well. Both research methods were prepared and performed with academic rigour to ensure high data quality. All survey participants had superior roles in IT or SCM and could be expected to have thorough knowledge regarding the use of SCP software. Likewise, different experts in the domain SCP were interviewed in the qualitative study of this research. Managers of food producers provided insights on the decision-making process to adopt APS. The insights of practitioners from the food industry were complemented by the views of software vendors and management consultants. The triangulation of different perspectives led to a holistic understanding regarding APS adoption by companies. In the following the research outcome concerning the three research questions is summarised.

RQ1: To what extent are APS implemented in the food industry?

Only a small fraction of companies in the food industry has implemented APS modules to support SCP practices. PP&S is supported the most by specialised software in companies. Many firms use basic functions of ERP systems or generic tools such as Excel for SCP.

Lack of human resources was revealed as major barrier to APS adoption. Many food companies are inhibited to implement sophisticated SCP because the know-how inside the organisation to implement and operate the systems is considered as insufficient. Furthermore, skilled staff to support the introduction of APS modules has in many firms not the time capacities for another project. The research also indicated that decision-makers in some companies are not familiar with specialised software for SCP. Individual food companies also decide against APS as the introduction of SCP software is not considered as a promising business case. Firms might not have the required financial resources for a new software and the associated implementation project. The research findings showed that food companies using SCP software are larger in size. Other firms may not need specialised software for SCP due to less complex business processes. The use of ERP systems or spreadsheets for SCP is thus considered as sufficient.

The research indicated that food producers are induced to implement specialised software for SCP in order to adapt to increased supply chain complexity. Once supply chain processes exceed a certain level of complexity, the efficiency and effectiveness of SCP based on less sophisticated methods is reduced. Moreover, firms adopt APS to achieve company goals such as enhanced reliability to the customer or reduced food waste. Overall, the research showed that functions of APS modules are viewed as highly useful by managers in the food industry. Anticipated benefits of APS could be materialised in most companies that had introduced SCP software.

RQ2: What are the antecedents affecting the PU and the PEOU of APS that lead to the adoption of such software tools?

PU and PEOU are well acknowledged determinants of technology adoption. Different company and system characteristics were identified as antecedents of PU and PEOU regarding APS in this research. The company characteristics include SC complexity, data quality, expertise, and the difficulty of the technical integration with SCP software. SC complexity and data quality are expected to be positively related to PU of APS. Companies with complex processes require specialised software to effectively manage products along the supply chain. Moreover, data needs to be well maintained so that companies can benefit from the output of APS modules. Poor data quality leads to inaccurate plans and consequently reduced usefulness of SCP software. Expertise in firms is expected to be positively related to PEOU of APS. Experienced personnel facilitate the implementation of new software and require less training to assimilate the skills needed to operate APS. Highly customised ERP systems can impede the integration with APS modules. Increased difficulty of the technical integration with APS is expected to be negatively related to PEOU.

The system characteristics affecting PU and PEOU include coverage of company requirements, relevance of functionalities, usability, and the difficulty of the technical integration with the ERP system. Coverage of company requirements and relevance of software functions are expected to be positively related to PU of SCP software. APS modules are usually customised corresponding to supply chain processes. If company-specific requirements are fulfilled, software will enable supply chain planners to perform tasks more effectively. Similarly, APS with more pertinent functions to support business processes are considered as more useful. In addition, software usability is expected to be positively related to PEOU. A well-structured user interface contributes to intuitive usage of the system. Likewise, less effort is required to learn how to operate the software. Lastly, APS modules should be capable to be interfaced with ERP systems. Increased difficulty of the technical integration with the ERP system is expected to be negatively related to PEOU of SCP software.

The APS adoption model was developed based on this research and existing literature. The validated model incorporates the determined antecedents of PU and PEOU of APS. PU and PEOU are expected to affect management support regarding the adoption of specialised software for SCP.

RQ 3: How can APS implementations be facilitated?

APS modules do not automatically translate into benefits. Software implementations can also fail. The qualitative study of this research uncovered different advice to enhance the introduction of APS. If the five suggestions are followed, the likelihood to reap the benefits of SCP software might be increased.

Firstly, companies need to assign competent staff to the project. The project team for the implementation of APS usually consists of process experts, IT experts and project managers. Ideally project team members are freed from daily operations to be focused on the introduction of the new software.

Secondly, the research showed that management commitment to the introduction of APS is essential and should be maintained throughout the whole project. Management needs to drive the change in the organisation. Stakeholders should be informed regarding the purpose of the project. The staff should have a solid understanding why a new software is introduced. This might positively affect acceptance among employees. The implementation project should further not lose management priority, if parallel IT projects are initiated.

Thirdly, APS modules require customisation according to supply chain processes. Therefore, process experts need to highlight requirements towards IT service providers. Poor customisation can imply that the system is not utilised to its full capacity or might not fulfil its purpose.

Fourthly, the models incorporated in APS modules rely usually on data from ERP systems. Well maintained data are thus a prerequisite for the introduction of APS. Poor data quality can lead to biased system output of decision support tools. The resulting dissatisfaction by stakeholders can impede assimilation of the new software within the organisation.

Lastly, companies should strategically reflect on supply chain processes in conjunction with company goals. Firms have different options to support SCP. Individual companies require sophisticated software to perform SCP tasks. In other firms basic functions in ERP systems or spreadsheet-based planning can be sufficient. Targeted selection of software for SCP is the basis of successful system implementation.

7.3 Contribution and Implications

This research has theoretical and practical implications. The study contributes to the literature in several ways. In the past decades research regarding SCP in the food industry was focused on the development of sophisticated models customised for different food supply chains. Empirical investigations concerning the implementation of such models are scarce. The same holds for studies on APS as technological enabler of SCP. Empirical research with regard to the implementation of APS was demanded iteratively by different scholars (Rudberg and Thulin 2009; Zago and Mesquita 2015; Jonsson and Ivert 2015). Likewise, literature in the domain of SCP was criticised to lack practical relevance (Jonsson and Holmström 2016). The findings of this mixed methods research are based on the experience and observations of experts from practice. The empirical evidence based on the quantitative and qualitative data provides a better understanding of APS implementation in the food industry. In addition, the research findings add to the literature of technology adoption. Lots of research has been conducted in the field of technology adoption. The TAM by Davis et al. (1989) is a widely acknowledged framework to understand the adoption of IT systems. The adoption of various technologies has been examined in the past (Amoako-Gyampah and Salam 2004; Gao and Bai 2014; Lee 2009). Studies on the adoption of APS modules by companies are rare though. By means of mixed methods research insights regarding different considerations leading to the adoption of APS modules (e.g. drivers and barriers to APS adoption) were gathered. Based on the findings an adapted TAM for the context of APS was established. Overall, the research leads to a better understanding of technology adoption behaviour of companies in terms of APS. This was particularly fostered by the combination of quantitative and qualitative methods. Furthermore, the triangulation of different perspectives from managers of food companies, software vendors and consultants contributed to comprehensive evidence on APS adoption.

This research has also different implications for practice. Companies in the food industry might benefit from the research findings. Many food producers rely on sophisticated methods for SCP. APS constitute the technological means for that and enable firms to become more resilient against disruptions as experienced through the COVID-19 pandemic and the war in Ukraine. This research investigated organisational requirements regarding the implementation of APS based on the views from experts in that field. The findings should be particularly of interest for companies considering the adoption of APS modules. The research should give managers a better understanding of prerequisites for the implementation of SCP software. Additionally, the study raises awareness among decision-makers about difficulties in implementation projects and how to prevent them. The qualitative research revealed practical advice to facilitate the introduction of SCP software.

Although the findings were based on interviews with managers from the food industry and external experts, the results may also be relevant for practitioners in other industries.

Likewise, the findings of this research are useful for software firms. Different requirements for SCP software were identified in this research. For example, software usability and the capability for technical integration with ERP systems system were highlighted apart from software functionalities. Furthermore, the research provides valuable insights for software vendors regarding different considerations within companies affecting the decision to invest in APS. Managers from software firms might be interested into aspects that inhibit companies to introduce SCP software. In particular, the APS adoption model developed in this research gives an overview of different factors that might impact the PU and PEOU of APS. The determined antecedents lead to an improved understanding how software modules are perceived by customers. The antecedents of PU and PEOU are differentiated between company and system characteristics. At least the identified system characteristics can be influenced by software vendors themselves. Based on the research findings software firms could derive directions to enhance APS modules in future releases. The research may thus also contribute to a better fit between customer needs and technological solutions for SCP.

7.4 Limitations

There are a few limitations associated with this research. One limitation of this research is the low sample size of the online survey. The low response rate limited the scope of possible data analyses. The data gathered in the quantitative study is still considered as valuable contribution for the evaluation of APS implementation in the food industry. The survey instrument consisted of questions that only senior employees could possibly answer. For example, the survey queried plans to adopt APS modules in the future or asked participants to assess barriers to software implementation. The survey participants in this research can be expected to be well-informed about SCP practices and software to support these. Furthermore, the data sample was enriched by qualitative interview data. The expert interviews provided additional insights on the adoption of APS, but also added meaning to the survey data. Due to the low sample size the findings cannot be generalised though.

Another shortcoming of this research is the low proportion of practitioners from food companies interviewed in the qualitative study. Three managers of food companies were interviewed compared to five managers of software firms and seven management consultants. More insights from food companies could have benefited the research outcome to reveal perceptions of practitioners within the industry regarding sophisticated SCP software. Yet, the interviews with the consultants and software firms could provide useful evidence on technology adoption behaviour of companies in terms of APS. After several iterations additional interviews led to only minor incremental insights. In addition, the data was complemented well with the quantitative data gathered by the survey.

Thirdly, two interviewed managers from the food industry were involved in the implementation of APS in their companies. APS could thus be viewed more favourable by them. The qualitative data was analysed with academic rigour though. Moreover, the interviewed consultants provided a neutral perspective on APS implementation.

Fourthly, this research investigated technology adoption of companies across different APS modules. Different factors leading to the decision to adopt APS modules were investigated. Antecedents of PU and PEOU might vary between different APS modules such as software for S&OP and PP&S. This mixed methods research was exploratory and provided a holistic view on APS adoption without a focus on specific APS modules. Despite the limitations, the research provides useful information for companies and adds to the technology adoption literature.

7.5 Suggestions for Further Research

Future studies can expand the findings of this research in different ways. Firstly, there are multiple options to further enhance the understanding of APS adoption by means of case studies. This mixed methods research was inductive and provided a broad view on APS adoption of organisations. Based on the APS adoption model different research propositions were derived regarding antecedents of PU and PEOU in terms of APS. Each of the antecedents can be studied more in depth in future research. For example, case studies could investigate how PU of APS is affected by data quality. Moreover, antecedents of PU and PEOU could vary between APS modules. The antecedents of the adoption of specific APS modules could be examined in case studies as well. Likewise, supply chains differ across food sectors. Future research could focus on individual food sectors. Case studies give the opportunity to analyse the adoption of APS within selected companies from different perspectives.

Secondly, the research propositions could be empirically tested in future research. The expected relationships could be generalised based on more large-scale studies. Thirdly, future research could extend the APS adoption model by further factors. This research revealed company and system characteristics as antecedents of PU and PEOU. Individual characteristics of decision-makers or industry characteristics might impact the decision to adopt SCP software as well. Additionally, longitudinal studies on software implementations in companies could be valuable to identify critical success factors for the introduction of APS. Lastly, future investigations could examine the business case of APS. A positive business case was stated several times during the interviews as prerequisite for the management decision to adopt APS. It is expected that high PU and PEOU coincide with a positive business case. Future research could quantify the usefulness of APS modules and determine the business case of APS implementations.

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Appendices

Appendix 1: Survey

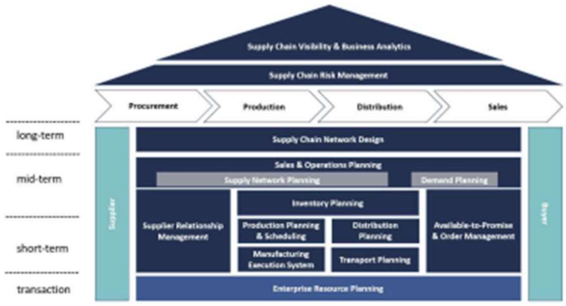
English

Introductory questions

Survey on supply chain planning in the food industry

Changing consumer attitudes, a growing product variety and the management of shelf lives across all stages of the production process, among other factors, make supply chain management in the food industry very complex. Therefore, integrated supply chain planning is essential for food companies. Planning problems can be solved by dedicated software tools (Advanced Planning Systems = APS).

APS comprise different software modules involving functionalities to support long-term, mid-term and short-term decision-making. Thereby, an efficient use of resources along the supply chain can be ensured. The framework below gives an overview of software modules covered by APS.



The following survey is supposed to provide insights into the use of software tools to support supply chain management within the food industry.

As participant, you will...

- ...have the opportunity to receive a comprehensive feedback report regarding the outcome of the survey.
- ...ensure that your experiences are included in the analyses.

The survey should take about 10 to 20 minutes to complete. If you have any questions, please contact David Stüve (david.stuve@strath.ac.uk).

Responses will be analysed in aggregated form and individual survey respondents will not be identified in the published results. We will not share your contact data with any third parties.

In which industry are you predominantly operating?

- ○ Meat & meat products
- ○ Fish
- ○ Dairy
- ○ Fruit & vegetables
- ○ Sweets & snacks
- ○ Frozen food
- ○ Baked goods
- ○ Convenience products
- ○ Alcoholic beverages
- ○ Non-alcoholic beverages
- ○ Nutriments
- ○ Tinned food
- ○ Soups & sauces
- ○ [ ] Other (please specify)

In which country are you located?

[Germany ▾]

How many employees are working at your company?

- ○ Less than 10
- ○ 10 - 19
- ○ 20 - 49
- ○ 50 - 99
- ○ 100 - 249
- ○ 250 - 499
- ○ 500 - 999
- ○ More than 1,000

What is the revenue of your company? (in € mil.)

- ○ Less than 10
- ○ 10 - 19
- ○ 20 - 49
- ○ 50 - 99
- ○ 100 - 249
- ○ 250 - 499
- ○ 500 - 999

○ More than 1,000

What is your role in the company?

○ CEO
○ Head of IT
○ Head of SCM
○ Head of Logistics
○ [ ] Other (please specify)

Do you want to receive feedback regarding the outcome of the survey?

○ Yes
○ No

Please indicate your email address to receive a feedback report.

[ ]

Use of software modules

Which of the following software/software modules to support supply chain planning do you use or are you planning to use? *(hover your mouse over the software/software module to see a detailed description of functions typically included in the respective software/software module)*

	In use	Implementation planned within next 2 years	Implementation planned within next 2 to 5 years	No implementation planned
Supply chain network design	○	○	○	○
Sales & operations planning	○	○	○	○
Inventory planning	○	○	○	○
Supplier relationship management	○	○	○	○
Available-to-promise & order management	○	○	○	○
Production planning & scheduling	○	○	○	○
Distribution planning	○	○	○	○
Manufacturing execution system	○	○	○	○

	In use	Implementation planned within next 2 years	Implementation planned within next 2 to 5 years	No implementation planned
Transport planning	○	○	○	○
Other (please specify) [ ]	○	○	○	○

What is the name of the software/software module that is used for **supply chain network design**?

[ ]

If a software/software module for **supply chain network design** has already been selected, what is the name of the software/software module that you are planning to implement?

[ ]

What is the name of the software/software module that is used for **sales & operations planning**?

[ ]

If a software/software module for sales & operations planning has already been selected, what is the name of the software/software module that you are planning to implement?

[ ]

What is the name of the software/software module that is used for **inventory planning**?

[ ]

If a software/software module for **inventory planning** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the software/software module that is used for **supplier relationship management**?

If a software/software module for **supplier relationship management** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the software/software module that is used for **available-to-promise & order management**?

If a software/software module for **available-to-promise & order management** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the software/software module that is used for **production planning & scheduling**?

If a software/software module for **production planning & scheduling** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the **manufacturing execution system** that is used?

If a **manufacturing execution system** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the software/software module that is used for **distribution planning**?

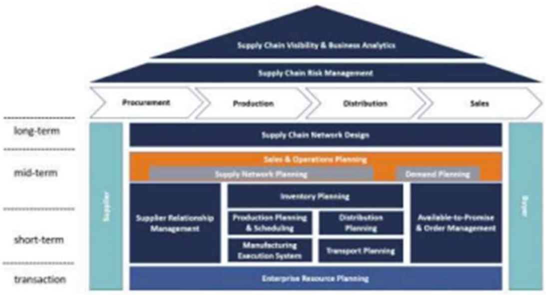
If a software/software module for **distribution planning** has already been selected, what is the name of the software/software module that you are planning to implement?

What is the name of the software/software module that is used for **transport planning**?

If a software/software module for **transport planning** has already been selected, what is the name of the software/software module that you are planning to implement?

Sales & operations planning

The following section covers the use of a software/software module for **Sales & Operations Planning.**



How familiar are you with software/software modules for **sales & operations planning**?

Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
○	○	○	○	○

In how far have the following factors (negatively) influenced your decision regarding the implementation of a software/software module for **sales & operations planning**?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	○	○	○	○	○
There is a lack of expertise to use the software.	○	○	○	○	○
There is a lack of data quality to use the software.	○	○	○	○	○
There is a lack of time for an implementation project.	○	○	○	○	○
Specific company requirements cannot be covered.	○	○	○	○	○
Required interfaces to other systems are too expensive/complex to set up and to maintain.	○	○	○	○	○
The functions are not relevant for our business model.	○	○	○	○	○
Other factors (please specify) ______	○	○	○	○	○

To what extent are the following functions covered in the software/software module for **sales & operations planning** and how do you evaluate the benefits for your company?

	Coverage of function				Perceived benefit				
	Extensively covered	Well covered	Partly covered	Not covered at all	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Statistical forecasting – assist the planner in making estimations derived from historical data	○	○	○	○	○	○	○	○	○
Incorporation of judgmental factors – to correct and improve statistical forecast (e.g. by consensus of experts)	○	○	○	○	○	○	○	○	○
Collaborative/consensus-based decision process – assures that input for the demand planning process can be collected from all involved departments	○	○	○	○	○	○	○	○	○
Accuracy measurement – accuracy measures such as the Mean Absolute Percentage Error (MAPE) or the Mean Absolute Deviation (MAD) can be used to track and evaluate forecast accuracy	○	○	○	○	○	○	○	○	○
Creation of unrestricted operations plan – calculation of net demand considering inventory and comparison of production quantities with available capacities	○	○	○	○	○	○	○	○	○
Bottleneck resolution – in case of bottlenecks automated generation of a feasible plan (e.g. by building up inventory or scheduling additional shifts)	○	○	○	○	○	○	○	○	○
Further included functions (please specify) [ ]	○	○	○	○	○	○	○	○	○

Which further functions would be needed to effectively support **sales & operations planning**?

[ ]

To what extent do you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No insight / not specified
The cost of the **sales & operations planning** software was significantly higher than the expected budgets.	○	○	○	○	○	○
The implementation project for the **sales & operations planning** software took significantly longer than expected.	○	○	○	○	○	○
The performance of the **sales & operations planning** software is significantly below the expected level.	○	○	○	○	○	○

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No insight / not specified
The anticipated benefits of the **sales & operations planning** software have not been materialized.	○	○	○	○	○	○

If there were any consultants involved in the implementation project for the **sales & operations planning** software, how do you assess their expertise?

	Strongly agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Strongly disagree	No consultants involved	No insight / not specified
The technological know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The industry know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The change management know-how of the consultants was satisfactory.	○	○	○	○	○	○	○

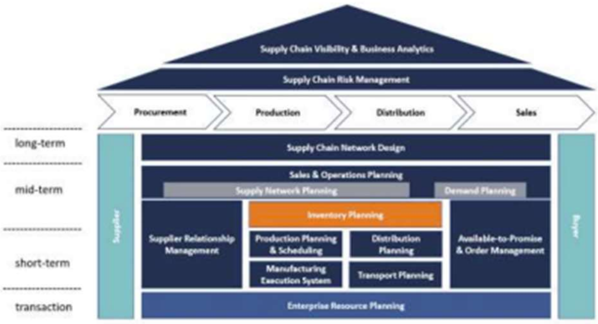
To what extent do you consider the following functions of a software/software module to support **sales & operations planning** as useful for your company?

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Statistical forecasting – assist the planner in making estimations derived from historical data	○	○	○	○	○
Incorporation of judgmental factors – to correct and improve statistical forecast (e.g. by consensus of experts)	○	○	○	○	○
Collaborative/consensus-based decision process – assures that input for the demand planning process can be collected from all involved departments	○	○	○	○	○
Accuracy measurement – accuracy measures such as the Mean Absolute Percentage Error (MAPE) or the Mean Absolute Deviation (MAD) can be used to track and evaluate forecast accuracy	○	○	○	○	○
Creation of unrestricted operations plan – calculation of net demand considering inventory and comparison of production quantities with available capacities	○	○	○	○	○

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Bottleneck resolution – in case of bottlenecks automated generation of a feasible plan (e.g. by building up inventory or scheduling additional shifts)	○	○	○	○	○

Inventory planning

The following section covers the use of a software/software module for **Inventory Planning**.



How familiar are you with **software/software modules** for **inventory planning**?

Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
○	○	○	○	○

In how far have the following factors (negatively) influenced your decision regarding the implementation of a software/software module for **inventory planning**?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	○	○	○	○	○
There is a lack of expertise to use the software.	○	○	○	○	○
There is a lack of data quality to use the software.	○	○	○	○	○
There is a lack of time for an implementation project.	○	○	○	○	○
Specific company requirements cannot be covered.	○	○	○	○	○
Required interfaces to other systems are too expensive/complex to set up and to maintain.	○	○	○	○	○

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The functions are not relevant for our business model.	○	○	○	○	○
Other factors (please specify) [ ]	○	○	○	○	○

To what extent are the following functions covered in the software/software module for **inventory planning** and how do you evaluate the benefits for your company?

	Coverage of function				Perceived benefit				
	Extensively covered	Well covered	Partly covered	Not covered at all	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Inventory management – includes features such as product categorization, product history and stock inquiries	○	○	○	○	○	○	○	○	○
Inventory level projection – includes calculation and display of accurate inventory levels for future periods	○	○	○	○	○	○	○	○	○
Inventory optimization – includes determination of optimal size of stocks, safety stock, reorder point, supply period, service level etc.	○	○	○	○	○	○	○	○	○
Order planning – includes features such as replenishment suggestions, creation of an order plan and upload of order proposal data to the connected purchasing system	○	○	○	○	○	○	○	○	○
Inventory tracking – includes features such as product tracking and audit trail	○	○	○	○	○	○	○	○	○
Stock-out and overstock alerts – includes alerts in case any product is in short supply, or in excess	○	○	○	○	○	○	○	○	○
Transfer management – includes features such as multi-location tracking, order picking, kitting and product bundling	○	○	○	○	○	○	○	○	○
Value added services – includes features such as labelling and manufacturing of displays	○	○	○	○	○	○	○	○	○
Further included functions (please specify) [ ]	○	○	○	○	○	○	○	○	○

Which further functions would be needed to effectively support **inventory planning**?

[ ]

To what extent do you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No insight / not specified
The cost of the **inventory planning** software was significantly higher than the expected budgets.	○	○	○	○	○	○
The implementation project for the **inventory planning** software took significantly longer than expected.	○	○	○	○	○	○
The performance of the **inventory planning** software is significantly below the expected level.	○	○	○	○	○	○
The anticipated benefits of the **inventory planning** software have not been materialized.	○	○	○	○	○	○

If there were any consultants involved in the implementation project for the **inventory planning** software, how do you assess their expertise?

	Strongly agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Strongly disagree	No consultants involved	No insight / not specified
The technological know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The industry know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The change management know-how of the consultants was satisfactory.	○	○	○	○	○	○	○

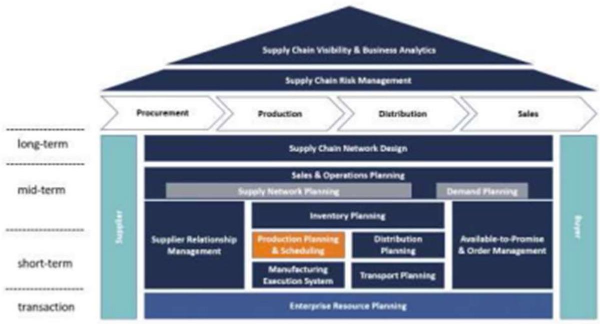
To what extent do you consider the following functions of a software/software module to support **inventory planning** as useful for your company?

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Inventory management – includes features such as product categorization, product history and stock inquiries	○	○	○	○	○
Inventory level projection – includes calculation and display of accurate inventory levels for future periods	○	○	○	○	○

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Inventory optimization – includes determination of optimal size of stocks, safety stock, reorder point, supply period, service level etc.	○	○	○	○	○
Order planning – includes features such as replenishment suggestions, creation of an order plan and upload of order proposal data to the connected purchasing system	○	○	○	○	○
Inventory tracking – includes features such as product tracking and audit trail	○	○	○	○	○
Stock-out and overstock alerts – includes alerts in case any product is in short supply, or in excess	○	○	○	○	○
Transfer management – includes features such as multi-location tracking, order picking, kitting and product bundling	○	○	○	○	○
Value added services – includes features such as labelling and manufacturing of displays	○	○	○	○	○

Production planning & scheduling

The following section covers the use of a software/software module for **Production Planning & Scheduling**.



How familiar are you with software/software modules for **production planning & scheduling**?

Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
○	○	○	○	○

In how far have the following factors (negatively) influenced your decision regarding the implementation of a software/software module for **production planning & scheduling**?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	○	○	○	○	○
There is a lack of expertise to use the software.	○	○	○	○	○
There is a lack of data quality to use the software.	○	○	○	○	○
There is a lack of time for an implementation project.	○	○	○	○	○
Specific company requirements cannot be covered.	○	○	○	○	○
Required interfaces to other systems are too expensive/complex to set up and to maintain.	○	○	○	○	○
The functions are not relevant for our business model.	○	○	○	○	○
Other factors (please specify) [ ]	○	○	○	○	○

To what extent are the following functions covered in the software/software module for **production planning & scheduling** and how do you evaluate the benefits for your company?

	Coverage of function				Perceived benefit				
	Extensively covered	Well covered	Partly covered	Not covered at all	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Dynamic lot-sizing – definition of quantity of an item to manufacture in a single production run	○	○	○	○	○	○	○	○	○
Automated scheduling – algorithm-based scheduling and sequencing of production orders	○	○	○	○	○	○	○	○	○
Manual scheduling – to correct and improve production schedules by input of dispatchers etc.	○	○	○	○	○	○	○	○	○
Shop floor control – comprises methods and systems to prioritize, track, and report against production orders and schedules	○	○	○	○	○	○	○	○	○
Rescheduling of orders – enabled by drag & drop functionality in an interactive planning board	○	○	○	○	○	○	○	○	○
Further included functions (please specify) [ ]	○	○	○	○	○	○	○	○	○

Which further functions would be needed to effectively support **production planning & scheduling**?

[ ]

To what extent do you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No insight / not specified
The cost of the **production planning & scheduling** software was significantly higher than the expected budgets.	○	○	○	○	○	○
The implementation project for the **production planning & scheduling** software took significantly longer than expected.	○	○	○	○	○	○
The performance of the **production planning & scheduling** software is significantly below the expected level.	○	○	○	○	○	○
The anticipated benefits of the **production planning & scheduling** software have not been materialized.	○	○	○	○	○	○

If there were any consultants involved in the implementation project for the **production planning & scheduling** software, how do you assess their expertise?

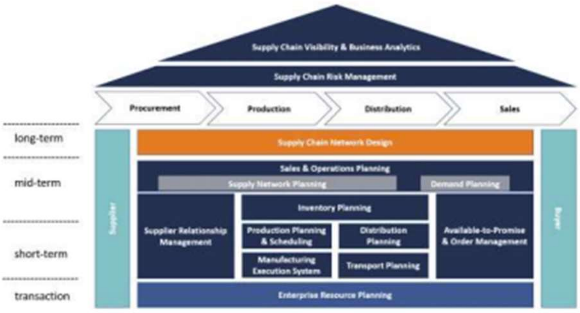
	Strongly agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Strongly disagree	No consultants involved	No insight / not specified
The technological know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The industry know-how of the consultants was satisfactory.	○	○	○	○	○	○	○
The change management know-how of the consultants was satisfactory.	○	○	○	○	○	○	○

To what extent do you consider the following functions of a software/software module to support **production planning & scheduling** as useful for your company?

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Dynamic lot-sizing – definition of quantity of an item to manufacture in a single production run	○	○	○	○	○
Automated scheduling – algorithm-based scheduling and sequencing of production orders	○	○	○	○	○
Manual scheduling – to correct and improve production schedules by input of dispatchers etc.	○	○	○	○	○
Shop floor control – comprises methods and systems to prioritize, track, and report against production orders and schedules	○	○	○	○	○
Rescheduling of orders – enabled by drag & drop functionality in an interactive planning board	○	○	○	○	○

Supply chain network design

The following section covers the use of a software/software module for **Supply Chain Network Design**.



How familiar are you with software/software modules for **supply chain network design**?

Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
○	○	○	○	○

In how far have the following factors (negatively) influenced your decision regarding the implementation of a software/software module for **supply chain network design**?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	○	○	○	○	○

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
There is a lack of expertise to use the software.	○	○	○	○	○
There is a lack of data quality to use the software.	○	○	○	○	○
There is a lack of time for an implementation project.	○	○	○	○	○
Specific company requirements cannot be covered.	○	○	○	○	○
Required interfaces to other systems are too expensive/complex to set up and to maintain.	○	○	○	○	○
The functions are not relevant for our business model.	○	○	○	○	○
Other factors (please specify) [ ]	○	○	○	○	○

To what extent are the following functions covered in the software/software module for **supply chain network design** and how do you evaluate the benefits for your company?

	Coverage of function				Perceived benefit				
	Extensively covered	Well covered	Partly covered	Not covered at all	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Determination of product strategy – includes number and main characteristics of products as well as markets to be served	○	○	○	○	○	○	○	○	○
Determination of manufacturing strategy – includes number and location of plants, sourcing strategy, investment decisions and supplier selection	○	○	○	○	○	○	○	○	○
Determination of logistics strategy – includes number, locations and echelons of distribution centers, sourcing strategy and investment decisions	○	○	○	○	○	○	○	○	○
Determination of procurement strategy – includes number of suppliers and selection of suppliers	○	○	○	○	○	○	○	○	○
Determination of investment/divestment decisions – includes in-/outsourcing, acquisitions/mergers and new technology introduction	○	○	○	○	○	○	○	○	○
Further included functions (please specify) [ ]	○	○	○	○	○	○	○	○	○

Which further functions would be needed to effectively support **supply chain network design**?

[ ]

To what extent do you agree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	No insight / not specified
The cost of the **supply chain network design** software was significantly higher than the expected budgets.	O	O	O	O	O	O
The implementation project for the **supply chain network design** software took significantly longer than expected.	O	O	O	O	O	O
The performance of the **supply chain network design** software is significantly below the expected level.	O	O	O	O	O	O
The anticipated benefits of the **supply chain network design** software have not been materialized.	O	O	O	O	O	O

If there were any consultants involved in the implementation project for the **supply chain network design** software, how do you assess their expertise?

	Strongly agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Strongly disagree	No consultants involved	No insight / not specified
The technological know-how of the consultants was satisfactory.	O	O	O	O	O	O	O
The industry know-how of the consultants was satisfactory.	O	O	O	O	O	O	O
The change management know-how of the consultants was satisfactory.	O	O	O	O	O	O	O

To what extent do you consider the following functions of a software/software module to support **supply chain network design** as useful for your company?

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Determination of product strategy – includes number and main characteristics of products as well as markets to be served	O	O	O	O	O

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Determination of manufacturing strategy – includes number and location of plants, sourcing strategy, investment decisions and supplier selection	○	○	○	○	○
Determination of logistics strategy – includes number, locations and echelons of distribution centers, sourcing strategy and investment decisions	○	○	○	○	○
Determination of procurement strategy – includes number of suppliers and selection of suppliers	○	○	○	○	○
Determination of investment/divestment decisions – includes in-/outsourcing, acquisitions/mergers and new technology introduction	○	○	○	○	○

Supply chain complexity

You are almost done! Please indicate your answers to the few remaining questions.

To what extent do you agree with the following statements with respect to your supply chain?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The demand is characterised by significant random variations.	○	○	○	○	○
Unplanned disturbances in the production process affecting the available capacity are very common.	○	○	○	○	○
Restrictions in available production capacity are very common.	○	○	○	○	○
The material needed to produce products stated in the production plan is usually received at the right time and in the right quantity.	○	○	○	○	○
The material needed to produce products stated in the production plan is usually delivered at the right quality.	○	○	○	○	○

Please indicate the average shelf life of your products.

○ Up to 10 days
○ Up to 30 days
○ Up to 6 months
○ More than 6 months

How many different products / stock keeping units (SKU) are included in your product portfolio?

- ○ Up to 100
- ○ Up to 500
- ○ Up to 2,000
- ○ Up to 5,000
- ○ Up to 10,000
- ○ More than 10,000

Appendix 2: Interview Guide for Managers of Food Companies and External Experts

Topics	Managers of food companies		
	APS is used	Implementation of APS is planned	APS is not used and implementation of APS is not planned
Requirements for APS adoption	1. Which requirements was the SCP software supposed to meet? 2. Which organisational measures have been taken to prepare for the implementation of SCP software?	1. Which requirements should the SCP software meet? 2. Which organisational measures have been taken to prepare for the implementation of SCP software?	1. If the implementation of SCP software has been considered in the past, what did you expect from an SCP software?
Usability of APS	3. Do you consider the SCP software as user-friendly? 4. What makes an SCP software user-friendly / not user-friendly? 5. How can the usability of the SCP software be improved?	3. Has the usability of the SCP software been assessed? 4. What makes an SCP software user-friendly / not user-friendly?	
Drivers of APS adoption & barriers to APS adoption	6. Why did you implement SCP software? 7. How did you plan the SC before? 8. Do you consider the implementation of the new SCP	5. Why do you plan to implement SCP software? 6. Why did you not implement SCP software before? 7. How did you plan the SC before?	2. Why are you not using SCP software? 3. Has the introduction of SCP software been considered? 4. Is SCP carried out with other

	software as success? 9. What are the most common factors preventing companies from implementing SCP software?	8. When do you consider the implementation of the new SCP software as success? 9. What are the most common factors preventing companies from implementing SCP software?	software tools (ERP system, Excel, etc.)? 5. Are current SCP processes performing well? 6. What are the most common factors preventing companies from implementing SCP software?
Use of the software	10. Do you consider the SCP software as useful? 11. Is there a certain SC complexity that the SCP software cannot cover? 12. What know-how is required to use the SCP software?		
Implementation projects	13. How long did the implementation project take? 14. Did you experience any challenges within the implementation project? 15. How can food companies prepare for implementation projects?	10. What are your expectations regarding the duration of the project? 11. What are your expectations regarding challenges within the implementation project?	

Topics	Managers of software vendors	Consultants
Requirements for APS adoption	1. Which requirements should the software meet so that the implementation makes sense for companies? 2. Which requirements should companies meet for the introduction of your software?	1. Which requirements should an SCP software meet so that the implementation makes sense for companies? 2. Which requirements should companies meet for the introduction of SCP software?
Usability of APS	3. What makes an SCP software user-friendly / not user-friendly? 4. How can the usability of SCP software be improved?	3. Do you assess the usability of SCP software in projects? 4. What makes an SCP software user-friendly / not user-friendly? 5. How can the usability of SCP software be improved?
Drivers of APS adoption & barriers to APS adoption	5. What benefits are food companies looking for when considering the implementation of your software? 6. What gives companies the impetus to introduce your software? 7. What are the most common factors preventing companies from implementing your software? 8. Why do many companies use ERP systems instead of APS for SCP?	6. What benefits are food companies looking for when considering the implementation of SCP software? 7. What gives companies the impetus to introduce SCP software? 8. What are the most common factors preventing companies from implementing SCP software? 9. Why do many companies use ERP systems instead of APS for SCP?
Use of the software	9. How can the effectiveness of your software be determined? 10. Is there a certain SC complexity that the software cannot cover?	10. Is there a certain complexity that SCP software cannot cover? 11. How can companies get the maximum benefit from SCP software?

	11. How can companies get the maximum benefit from the software? 12. What know-how is required in a company to use your software?	12. What know-how is required in a company to use SCP software?
Implementation projects	13. How long does an implementation project take on average? 14. What are the most common challenges for companies within implementation projects? 15. Why do implementation projects fail? 16. What kind of expertise is required in a company to successfully implement a software? 17. How can implementation projects be accelerated? 18. How can food companies prepare for implementation projects?	13. How long does an implementation project take on average? 14. What are the most common challenges for companies within implementation projects? 15. Why do implementation projects fail? 16. What kind of expertise is required in a company to successfully implement a software? 17. How can implementation projects be accelerated? 18. How can food companies prepare for implementation projects?

Appendix 3: Results Levene's Test

1. First wave & second wave of survey respondents

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
M_PU_SOP	Based on Mean	.570	1	30	.456
	Based on Median	.541	1	30	.468
	Based on Median and with adjusted df	.541	1	29.987	.468
	Based on trimmed mean	.565	1	30	.458
M_PU_IP	Based on Mean	1.942	1	26	.175
	Based on Median	1.537	1	26	.226
	Based on Median and with adjusted df	1.537	1	23.473	.227
	Based on trimmed mean	1.978	1	26	.171
M_PU_PPS	Based on Mean	.004	1	26	.953
	Based on Median	.013	1	26	.911
	Based on Median and with adjusted df	.013	1	22.804	.912
	Based on trimmed mean	.002	1	26	.961
M_PU_SCND	Based on Mean	.067	1	22	.799
	Based on Median	.052	1	22	.822
	Based on Median and with adjusted df	.052	1	21.956	.822
	Based on trimmed mean	.063	1	22	.804
Mean_ROI	Based on Mean	.696	1	19	.414
	Based on Median	.855	1	19	.367
	Based on Median and with adjusted df	.855	1	18.388	.367
	Based on trimmed mean	.776	1	19	.389
Mean_Expertise	Based on Mean	2.938	1	19	.103
	Based on Median	2.655	1	19	.120
	Based on Median and with adjusted df	2.655	1	16.918	.122
	Based on trimmed mean	3.024	1	19	.098
Mean_DataQuality	Based on Mean	.231	1	19	.636
	Based on Median	.377	1	19	.547
	Based on Median and with adjusted df	.377	1	18.739	.547
	Based on trimmed mean	.249	1	19	.624
Mean_Time	Based on Mean	.447	1	19	.512
	Based on Median	.416	1	19	.527
	Based on Median and with adjusted df	.416	1	18.986	.527
	Based on trimmed mean	.438	1	19	.516
Mean_CompanyRequirements	Based on Mean	2.140	1	19	.160
	Based on Median	.601	1	19	.448
	Based on Median and with adjusted df	.601	1	17.041	.449
	Based on trimmed mean	2.278	1	19	.148
Mean_Interfaces	Based on Mean	.968	1	19	.337
	Based on Median	.966	1	19	.338
	Based on Median and with adjusted df	.966	1	18.169	.339
	Based on trimmed mean	1.050	1	19	.318
Mean_Functions_not_relevant	Based on Mean	3.008	1	19	.099
	Based on Median	3.064	1	19	.096
	Based on Median and with adjusted df	3.064	1	16.866	.098
	Based on trimmed mean	3.114	1	19	.094

2. No consultants & consultants

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
M_PU_SOP	Based on Mean	1.214	1	30	.279
	Based on Median	.976	1	30	.331
	Based on Median and with adjusted df	.976	1	26.834	.332
	Based on trimmed mean	1.120	1	30	.298
M_PU_IP	Based on Mean	.358	1	26	.555
	Based on Median	.301	1	26	.588
	Based on Median and with adjusted df	.301	1	25.847	.588
	Based on trimmed mean	.361	1	26	.553
M_PU_PPS	Based on Mean	3.127	1	26	.089
	Based on Median	2.038	1	26	.165
	Based on Median and with adjusted df	2.038	1	12.708	.178
	Based on trimmed mean	2.838	1	26	.104
M_PU_SCND	Based on Mean	.736	1	22	.400
	Based on Median	.138	1	22	.714
	Based on Median and with adjusted df	.138	1	17.867	.715
	Based on trimmed mean	.613	1	22	.442
Mean_ROI	Based on Mean	1.006	1	19	.328
	Based on Median	.903	1	19	.354
	Based on Median and with adjusted df	.903	1	18.637	.354
	Based on trimmed mean	.902	1	19	.354
Mean_Expertise	Based on Mean	.017	1	19	.899
	Based on Median	.036	1	19	.851
	Based on Median and with adjusted df	.036	1	18.898	.851
	Based on trimmed mean	.006	1	19	.937
Mean_DataQuality	Based on Mean	.037	1	19	.849
	Based on Median	.263	1	19	.614
	Based on Median and with adjusted df	.263	1	18.480	.614
	Based on trimmed mean	.062	1	19	.805
Mean_Time	Based on Mean	.050	1	19	.826
	Based on Median	.032	1	19	.860
	Based on Median and with adjusted df	.032	1	18.459	.860
	Based on trimmed mean	.058	1	19	.812
Mean_CompanyRequirements	Based on Mean	.242	1	19	.629
	Based on Median	.207	1	19	.655
	Based on Median and with adjusted df	.207	1	18.590	.655
	Based on trimmed mean	.351	1	19	.560
Mean_Interfaces	Based on Mean	1.160	1	19	.295
	Based on Median	.879	1	19	.360
	Based on Median and with adjusted df	.879	1	18.998	.360
	Based on trimmed mean	1.132	1	19	.301
Mean_Functions_not_relevant	Based on Mean	.148	1	19	.705
	Based on Median	.002	1	19	.969
	Based on Median and with adjusted df	.002	1	17.268	.969
	Based on trimmed mean	.116	1	19	.737

Appendix 4: Differences regarding Supply Chain Complexity and Company Size between Companies Using and Not Using APS

a) Results of independent samples t-test

1. S&OP

Group Statistics

	Do you use software for SOP?	N	Mean	Std. Deviation	Std. Error Mean
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	12	2.25	1.215	.351
	No use of software	20	2.20	1.105	.247
M_production_uncertainty	Use of software	12	2.9167	.99620	.28758
	No use of software	20	2.7250	.97973	.21907
M_supply_uncertainty	Use of software	12	1.6667	.44381	.12812
	No use of software	20	2.2750	.54952	.12288
Please indicate the average shelf life of your products.	Use of software	12	3.50	1.168	.337
	No use of software	20	3.40	.940	.210
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	12	3.33	1.231	.355
	No use of software	20	2.40	1.392	.311
How many employees are working at your company?	Use of software	12	7.17	.937	.271
	No use of software	22	6.41	1.403	.299
What is the revenue of your company? (in € mil.)	Use of software	12	6.75	1.138	.329
	No use of software	21	5.33	1.713	.374

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Equal variances assumed	.271	.607	.119	30	.453	.906	.050	.419	-.805	.905
	Equal variances not assumed			.117	21.548	.454	.908	.050	.429	-.841	.941
M_production_uncertainty	Equal variances assumed	.003	.959	.532	30	.299	.598	.19167	.35996	-.54348	.92681
	Equal variances not assumed			.530	22.989	.301	.601	.19167	.36152	-.55621	.93954
M_supply_uncertainty	Equal variances assumed	.028	.868	-3.246	30	.001	.003	-.60833	.18743	-.99111	-.22555
	Equal variances not assumed			-3.427	27.213	<.001	.002	-.60833	.17752	-.97244	-.24423
Please indicate the average shelf life of your products.	Equal variances assumed	.057	.813	.266	30	.396	.792	.100	.376	-.668	.868
	Equal variances not assumed			.252	19.514	.402	.804	.100	.397	-.730	.930
How many different products / stock keeping units (SKU) are included in your product portfolio?	Equal variances assumed	.285	.597	1.915	30	.033	.065	.933	.487	-.062	1.929
	Equal variances not assumed			1.976	25.619	.030	.059	.933	.472	-.038	1.905
How many employees are working at your company?	Equal variances assumed	1.892	.179	1.672	32	.052	.104	.758	.453	-.165	1.680
	Equal variances not assumed			1.878	30.469	.035	.070	.758	.403	-.066	1.581
What is the revenue of your company? (in € mil.)	Equal variances assumed	2.749	.107	2.553	31	.008	.016	1.417	.555	.285	2.549
	Equal variances not assumed			2.847	30.134	.004	.008	1.417	.498	.401	2.433

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Cohen's d	1.147	.044	-.673	.759
	Hedges' correction	1.176	.043	-.656	.740
	Glass's delta	1.105	.045	-.671	.760
M_production_uncertainty	Cohen's d	.98580	.194	-.525	.910
	Hedges' correction	1.01133	.190	-.511	.887
	Glass's delta	.97973	.196	-.525	.911
M_supply_uncertainty	Cohen's d	.51330	-1.185	-1.952	-.401
	Hedges' correction	.52659	-1.155	-1.903	-.391
	Glass's delta	.54952	-1.107	-1.892	-.299
Please indicate the average shelf life of your products.	Cohen's d	1.030	.097	-.620	.812
	Hedges' correction	1.056	.095	-.604	.792
	Glass's delta	.940	.106	-.612	.821
How many different products / stock keeping units (SKU) are included in your product portfolio?	Cohen's d	1.335	.699	-.043	1.431
	Hedges' correction	1.370	.681	-.042	1.395
	Glass's delta	1.392	.671	-.084	1.409
How many employees are working at your company?	Cohen's d	1.262	.600	-.123	1.314
	Hedges' correction	1.293	.586	-.120	1.283
	Glass's delta	1.403	.540	-.188	1.256
What is the revenue of your company? (in € mil.)	Cohen's d	1.534	.924	.172	1.662
	Hedges' correction	1.572	.901	.167	1.622
	Glass's delta	1.713	.827	.064	1.572

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

2. IP

Group Statistics

	Do you use software for IP?	N	Mean	Std. Deviation	Std. Error Mean
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	12	2.50	1.243	.359
	No use of software	20	2.05	1.050	.235
M_production_uncertainty	Use of software	12	3.1250	1.06867	.30850
	No use of software	20	2.6000	.88258	.19735
M_supply_uncertainty	Use of software	12	1.7500	.39886	.11514
	No use of software	20	2.2250	.61719	.13801
Please indicate the average shelf life of your products.	Use of software	12	3.25	1.357	.392
	No use of software	20	3.55	.759	.170
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	12	3.00	1.206	.348
	No use of software	20	2.60	1.501	.336
How many employees are working at your company?	Use of software	12	7.25	.965	.279
	No use of software	22	6.36	1.364	.291
What is the revenue of your company? (in € mil.)	Use of software	12	6.75	.965	.279
	No use of software	21	5.33	1.770	.386

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p			Lower	Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Equal variances assumed	1.804	.189	1.096	30	.141	.282	.450	.411	-.389	1.289
	Equal variances not assumed			1.049	20.282	.153	.306	.450	.429	-.444	1.344
M_production_uncertainty	Equal variances assumed	1.099	.303	1.505	30	.071	.143	.52500	.34873	-.18720	1.23720
	Equal variances not assumed			1.434	19.915	.084	.167	.52500	.36622	-.23913	1.28913
M_supply_uncertainty	Equal variances assumed	.717	.404	-2.377	30	.012	.024	-.47500	.19986	-.88317	-.06683
	Equal variances not assumed			-2.643	29.755	.006	.013	-.47500	.17973	-.84219	-.10781
Please indicate the average shelf life of your products.	Equal variances assumed	6.828	.014	-.806	30	.213	.427	-.300	.372	-1.061	.461
	Equal variances not assumed			-.703	15.210	.246	.493	-.300	.427	-1.209	.609
How many different products / stock keeping units (SKU) are included in your product portfolio?	Equal variances assumed	2.189	.149	.782	30	.220	.440	.400	.511	-.644	1.444
	Equal variances not assumed			.827	27.296	.208	.415	.400	.484	-.592	1.392
How many employees are working at your company?	Equal variances assumed	1.127	.296	1.989	32	.028	.055	.886	.446	-.021	1.794
	Equal variances not assumed			2.200	29.615	.018	.036	.886	.403	.063	1.709
What is the revenue of your company? (in € mil.)	Equal variances assumed	5.135	.031	2.553	31	.008	.016	1.417	.555	.285	2.549
	Equal variances not assumed			2.974	30.979	.003	.006	1.417	.476	.445	2.388

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Cohen's d	1.125	.400	-.326	1.120
	Hedges' correction	1.154	.390	-.318	1.091
	Glass's delta	1.050	.429	-.305	1.151
M_production_uncertainty	Cohen's d	.95503	.550	-.184	1.274
	Hedges' correction	.97977	.536	-.179	1.242
	Glass's delta	.88258	.595	-.152	1.327
M_supply_uncertainty	Cohen's d	.54734	-.868	-1.610	-.113
	Hedges' correction	.56152	-.846	-1.569	-.110
	Glass's delta	.61719	-.770	-1.516	-.005
Please indicate the average shelf life of your products.	Cohen's d	1.020	-.294	-1.011	.428
	Hedges' correction	1.046	-.287	-.986	.417
	Glass's delta	.759	-.395	-1.117	.336
How many different products / stock keeping units (SKU) are included in your product portfolio?	Cohen's d	1.400	.286	-.436	1.003
	Hedges' correction	1.436	.279	-.425	.977
	Glass's delta	1.501	.267	-.458	.984
How many employees are working at your company?	Cohen's d	1.242	.714	-.016	1.433
	Hedges' correction	1.272	.697	-.016	1.399
	Glass's delta	1.364	.650	-.087	1.372
What is the revenue of your company? (in € mil.)	Cohen's d	1.534	.924	.172	1.662
	Hedges' correction	1.572	.901	.167	1.622
	Glass's delta	1.770	.800	.041	1.542

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

3. PP&S

Group Statistics

	Do you use software for PPS?	N	Mean	Std. Deviation	Std. Error Mean
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	14	2.00	1.109	.296
	No use of software	18	2.39	1.145	.270
M_production_uncertainty	Use of software	14	3.2143	.67123	.17939
	No use of software	18	2.4722	1.06374	.25073
M_supply_uncertainty	Use of software	14	1.7857	.46881	.12529
	No use of software	18	2.2500	.60025	.14148
Please indicate the average shelf life of your products.	Use of software	14	3.36	1.151	.308
	No use of software	18	3.50	.924	.218
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	14	2.79	1.311	.350
	No use of software	18	2.72	1.487	.351
How many employees are working at your company?	Use of software	14	6.64	1.216	.325
	No use of software	20	6.70	1.380	.309
What is the revenue of your company? (in € mil.)	Use of software	14	6.14	1.460	.390
	No use of software	19	5.63	1.802	.413

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Equal variances assumed	.234	.632	-.966	30	.171	.342	-.389	.403	-1.211	.433
	Equal variances not assumed			-.970	28.500	.170	.340	-.389	.401	-1.209	.432
M_production_uncertainty	Equal variances assumed	1.886	.180	2.277	30	.015	.030	.74206	.32591	.07647	1.40765
	Equal variances not assumed			2.407	28.942	.011	.023	.74206	.30829	.11148	1.37265
M_supply_uncertainty	Equal variances assumed	.308	.583	-2.381	30	.012	.024	-.46429	.19499	-.86250	-.06607
	Equal variances not assumed			-2.457	29.995	.010	.020	-.46429	.18898	-.85024	-.07833
Please indicate the average shelf life of your products.	Equal variances assumed	.864	.360	-.390	30	.350	.699	-.143	.366	-.891	.605
	Equal variances not assumed			-.379	24.572	.354	.708	-.143	.377	-.920	.634
How many different products / stock keeping units (SKU) are included in your product portfolio?	Equal variances assumed	.126	.726	.126	30	.450	.901	.063	.504	-.965	1.092
	Equal variances not assumed			.128	29.469	.449	.899	.063	.496	-.950	1.077
How many employees are working at your company?	Equal variances assumed	.176	.677	-.125	32	.451	.902	-.057	.459	-.991	.877
	Equal variances not assumed			-.128	30.214	.450	.899	-.057	.448	-.972	.858
What is the revenue of your company? (in € mil.)	Equal variances assumed	1.677	.205	.871	31	.195	.391	.511	.587	-.686	1.709
	Equal variances not assumed			.899	30.660	.188	.375	.511	.568	-.649	1.671

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Cohen's d	1.130	-.344	-1.045	.362
	Hedges' correction	1.159	-.336	-1.019	.353
	Glass's delta	1.145	-.340	-1.042	.373
M_production_uncertainty	Cohen's d	.91457	.811	.077	1.533
	Hedges' correction	.93826	.791	.075	1.494
	Glass's delta	1.06374	.698	-.048	1.425
M_supply_uncertainty	Cohen's d	.54718	-.849	-1.572	-.112
	Hedges' correction	.56135	-.827	-1.533	-.109
	Glass's delta	.60025	-.773	-1.508	-.019
Please indicate the average shelf life of your products.	Cohen's d	1.028	-.139	-.837	.562
	Hedges' correction	1.055	-.135	-.816	.547
	Glass's delta	.924	-.155	-.853	.548
How many different products / stock keeping units (SKU) are included in your product portfolio?	Cohen's d	1.414	.045	-.654	.743
	Hedges' correction	1.450	.044	-.637	.724
	Glass's delta	1.487	.043	-.657	.741
How many employees are working at your company?	Cohen's d	1.316	-.043	-.726	.640
	Hedges' correction	1.348	-.042	-.709	.625
	Glass's delta	1.380	-.041	-.724	.642
What is the revenue of your company? (in € mil.)	Cohen's d	1.667	.307	-.390	.999
	Hedges' correction	1.709	.299	-.381	.974
	Glass's delta	1.802	.284	-.416	.976

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

b) Results of Mann-Whitney U test

1. S&OP

Ranks

	Do you use software for SOP?	N	Mean Rank	Sum of Ranks
How many employees are working at your company?	Use of software	12	20.92	251.00
	No use of software	22	15.64	344.00
	Total	34		
What is the revenue of your company? (in € mil.)	Use of software	12	22.08	265.00
	No use of software	21	14.10	296.00
	Total	33		
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	12	16.58	199.00
	No use of software	20	16.45	329.00
	Total	32		
M_production_uncertainty	Use of software	12	17.83	214.00
	No use of software	20	15.70	314.00
	Total	32		
M_supply_uncertainty	Use of software	12	10.67	128.00
	No use of software	20	20.00	400.00
	Total	32		
Please indicate the average shelf life of your products.	Use of software	12	17.83	214.00
	No use of software	20	15.70	314.00
	Total	32		
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	12	20.67	248.00
	No use of software	20	14.00	280.00
	Total	32		

Test Statistics[a]

	How many employees are working at your company?	What is the revenue of your company? (in € mil.)	To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	M_production_uncertainty	M_supply_uncertainty	Please indicate the average shelf life of your products.	How many different products / stock keeping units (SKU) are included in your product portfolio?
Mann-Whitney U	91.000	65.000	119.000	104.000	50.000	104.000	70.000
Wilcoxon W	344.000	296.000	329.000	314.000	128.000	314.000	280.000
Z	-1.531	-2.321	-.041	-.632	-3.070	-.787	-1.994
Asymp. Sig. (2-tailed)	.126	.020	.967	.527	.002	.431	.046
Exact Sig. [2*(1-tailed Sig.)]	.146[b]	.022[b]	.985[b]	.552[b]	.005[b]	.552[b]	.053[b]

a. Grouping Variable: Do you use software for SOP?

b. Not corrected for ties.

2. IP

Ranks

	Do you use software for IP?	N	Mean Rank	Sum of Ranks
How many employees are working at your company?	Use of software	12	21.79	261.50
	No use of software	22	15.16	333.50
	Total	34		
What is the revenue of your company? (in € mil.)	Use of software	12	22.08	265.00
	No use of software	21	14.10	296.00
	Total	33		
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	12	18.54	222.50
	No use of software	20	15.28	305.50
	Total	32		
M_production_uncertainty	Use of software	12	19.88	238.50
	No use of software	20	14.48	289.50
	Total	32		
M_supply_uncertainty	Use of software	12	11.83	142.00
	No use of software	20	19.30	386.00
	Total	32		
Please indicate the average shelf life of your products.	Use of software	12	16.25	195.00
	No use of software	20	16.65	333.00
	Total	32		
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	12	18.46	221.50
	No use of software	20	15.33	306.50
	Total	32		

Test Statistics[a]

	How many employees are working at your company?	What is the revenue of your company? (in € mil.)	To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	M_production_uncertainty	M_supply_uncertainty	Please indicate the average shelf life of your products.	How many different products / stock keeping units (SKU) are included in your product portfolio?
Mann-Whitney U	80.500	65.000	95.500	79.500	64.000	117.000	96.500
Wilcoxon W	333.500	296.000	305.500	289.500	142.000	195.000	306.500
Z	-1.923	-2.321	-1.002	-1.599	-2.456	-.147	-.937
Asymp. Sig. (2-tailed)	.054	.020	.316	.110	.014	.883	.349
Exact Sig. [2*(1-tailed Sig.)]	.063[b]	.022[b]	.346[b]	.116[b]	.029[b]	.924[b]	.366[b]

a. Grouping Variable: Do you use software for IP?

b. Not corrected for ties.

3. PP&S

Ranks

	Do you use software for PPS?	N	Mean Rank	Sum of Ranks
How many employees are working at your company?	Use of software	14	16.89	236.50
	No use of software	20	17.93	358.50
	Total	34		
What is the revenue of your company? (in € mil.)	Use of software	14	18.54	259.50
	No use of software	19	15.87	301.50
	Total	33		
To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	Use of software	14	14.64	205.00
	No use of software	18	17.94	323.00
	Total	32		
M_production_uncertainty	Use of software	14	21.00	294.00
	No use of software	18	13.00	234.00
	Total	32		
M_supply_uncertainty	Use of software	14	13.04	182.50
	No use of software	18	19.19	345.50
	Total	32		
Please indicate the average shelf life of your products.	Use of software	14	16.21	227.00
	No use of software	18	16.72	301.00
	Total	32		
How many different products / stock keeping units (SKU) are included in your product portfolio?	Use of software	14	17.00	238.00
	No use of software	18	16.11	290.00
	Total	32		

Test Statistics[a]

	How many employees are working at your company?	What is the revenue of your company? (in € mil.)	To what extent do you agree with the following statements with respect to your supply chain? - The demand is characterised by significant random variations.	M_production_uncertainty	M_supply_uncertainty	Please indicate the average shelf life of your products.	How many different products / stock keeping units (SKU) are included in your product portfolio?
Mann-Whitney U	131.500	111.500	100.000	63.000	77.500	122.000	119.000
Wilcoxon W	236.500	301.500	205.000	234.000	182.500	227.000	290.000
Z	-.308	-.796	-1.037	-2.428	-2.076	-.192	-.272
Asymp. Sig. (2-tailed)	.758	.426	.300	.015	.038	.848	.785
Exact Sig. [2*(1-tailed Sig.)]	.769[b]	.439[b]	.338[b]	.016[b]	.065[b]	.896[b]	.808[b]

a. Grouping Variable: Do you use software for PPS?

b. Not corrected for ties.

Appendix 5: Differences regarding Average Perceived Usefulness of APS Functions between Companies Using and Not Using APS

a) Results of independent samples t-test

1. S&OP

Group Statistics

	Which of the following software/software modules to support supply chain planning do you use or are you planning to use? (hover your mouse over the software/software module to see a detailed description of functions typically included in the respective software/software module) - Sales & operations planning	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	>= 2	21	1.9921	.41991	.09163
	< 2	11	2.1167	.42915	.12939

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.076	.785	-.791	30	.217	.435	-.12460	.15744	-.44614	.19694
	Equal variances not assumed			-.786	20.027	.221	.441	-.12460	.15855	-.45531	.20610

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.42301	-.295	-1.025	.441
	Hedges' correction	.43397	-.287	-1.000	.430
	Glass's delta	.42915	-.290	-1.024	.457

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

2. IP

Group Statistics

	Which of the following software/software modules to support supply chain planning do you use or are you planning to use? (hover your mouse over the software/software module to see a detailed description of functions typically included in the respective software/software module) - Inventory planning	N	Mean	Std. Deviation	Std. Error Mean
M_PU_IP	>= 2	19	2.1338	.58804	.13491
	< 2	9	2.6667	.73154	.24385

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_IP	Equal variances assumed	.524	.476	-2.072	26	.024	.048	-.53289	.25722	-1.06162	-.00417
	Equal variances not assumed			-1.912	13.101	.039	.078	-.53289	.27868	-1.13447	.06868

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_IP	Cohen's d	.63565	-.838	-1.656	-.006
	Hedges' correction	.65476	-.814	-1.607	-.006
	Glass's delta	.73154	-.728	-1.577	.157

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

3. PP&S

Group Statistics

	Which of the following software/software modules to support supply chain planning do you use or are you planning to use? (hover your mouse over the software/software module to see a detailed description of functions typically included in the respective software/software module) - Production planning & scheduling	N	Mean	Std. Deviation	Std. Error Mean
M_PU_PPS	>= 2	17	2.2853	.81159	.19684
	< 2	11	2.3091	.55399	.16704

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_PPS	Equal variances assumed	.300	.588	-.085	26	.466	.933	-.02380	.27994	-.59922	.55163
	Equal variances not assumed			-.092	25.873	.464	.927	-.02380	.25816	-.55458	.50698

Independent Samples Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
M_PU_PPS	Cohen's d	.72345	-.033	-.791	.726
	Hedges' correction	.74519	-.032	-.768	.705
	Glass's delta	.55399	-.043	-.801	.717

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

b) Results of Mann-Whitney U test

1. S&OP

Ranks

	Do you use software for SOP?	N	Mean Rank	Sum of Ranks
M_PU_SOP	Use of software	11	18.09	199.00
	No use of software	21	15.67	329.00
	Total	32		

Test Statistics[a]

	M_PU_SOP
Mann-Whitney U	98.000
Wilcoxon W	329.000
Z	-.701
Asymp. Sig. (2-tailed)	.483
Exact Sig. [2*(1-tailed Sig.)]	.506[b]

a. Grouping Variable: Do you use software for SOP?

b. Not corrected for ties.

2. IP

Ranks

	Do you use software for IP?	N	Mean Rank	Sum of Ranks
M_PU_IP	Use of software	9	19.00	171.00
	No use of software	19	12.37	235.00
	Total	28		

Test Statistics[a]

	M_PU_IP
Mann-Whitney U	45.000
Wilcoxon W	235.000
Z	-1.999
Asymp. Sig. (2-tailed)	.046
Exact Sig. [2*(1-tailed Sig.)]	.048[b]

a. Grouping Variable: Do you use software for IP?

b. Not corrected for ties.

3. **PP&S**

Ranks

	Do you use software for PPS?	N	Mean Rank	Sum of Ranks
M_PU_PPS	Use of software	11	16.27	179.00
	No use of software	17	13.35	227.00
	Total	28		

Test Statistics[a]

	M_PU_PPS
Mann-Whitney U	74.000
Wilcoxon W	227.000
Z	-.930
Asymp. Sig. (2-tailed)	.352
Exact Sig. [2*(1-tailed Sig.)]	.378[b]

a. Grouping Variable: Do you use software for PPS?

b. Not corrected for ties.

Appendix 6: Differences regarding Average Perceived Usefulness of APS Functions between Companies with Different Supply Chain Complexity and Company Size

a) Results of independent samples t-test

1. Demand uncertainty

Group Statistics

	Demand_uncertainty	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	Demand uncertainty	22	2.0583	.36910	.07869
	No demand uncertainty	8	1.8333	.37796	.13363
M_PU_IP	Demand uncertainty	20	2.3271	.60370	.13499
	No demand uncertainty	8	2.2500	.86860	.30710
M_PU_PPS	Demand uncertainty	20	2.2650	.82989	.18557
	No demand uncertainty	7	2.3500	.27234	.10293
M_PU_SCND	Demand uncertainty	17	2.8706	1.12459	.27275
	No demand uncertainty	7	2.7429	1.11184	.42024

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.008	.930	1.468	28	.077	.153	.22500	.15331	-.08904	.53904
	Equal variances not assumed			1.451	12.207	.086	.172	.22500	.15508	-.11225	.56225
M_PU_IP	Equal variances assumed	2.440	.130	.269	26	.395	.790	.07708	.28663	-.51209	.66625
	Equal variances not assumed			.230	9.831	.411	.823	.07708	.33546	-.67210	.82627
M_PU_PPS	Equal variances assumed	1.718	.202	-.263	25	.397	.795	-.08500	.32308	-.75039	.58039
	Equal variances not assumed			-.401	24.997	.346	.692	-.08500	.21220	-.52205	.35205
M_PU_SCND	Equal variances assumed	.025	.876	.254	22	.401	.802	.12773	.50349	-.91644	1.17190
	Equal variances not assumed			.255	11.364	.402	.803	.12773	.50099	-.97065	1.22612

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.37134	.606	-.224	1.425
	Hedges' correction	.38167	.590	-.218	1.387
	Glass's delta	.37796	.595	-.288	1.442
M_PU_IP	Cohen's d	.68517	.113	-.709	.932
	Hedges' correction	.70576	.109	-.688	.905
	Glass's delta	.86860	.089	-.736	.907
M_PU_PPS	Cohen's d	.73568	-.116	-.976	.747
	Hedges' correction	.75871	-.112	-.946	.724
	Glass's delta	.27234	-.312	-1.178	.578
M_PU_SCND	Cohen's d	1.12113	.114	-.768	.993
	Hedges' correction	1.16125	.110	-.742	.959
	Glass's delta	1.11184	.115	-.772	.993

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

2. Production uncertainty

Group Statistics

	Production_uncertainty	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	Production uncertainty	14	1.9405	.30387	.08121
	No production uncertainty	16	2.0490	.43739	.10935
M_PU_IP	Production uncertainty	13	2.0705	.71895	.19940
	No production uncertainty	15	2.5083	.57954	.14964
M_PU_PPS	Production uncertainty	14	1.9786	.49018	.13101
	No production uncertainty	13	2.6192	.79988	.22185
M_PU_SCND	Production uncertainty	10	2.5200	1.15547	.36539
	No production uncertainty	14	3.0571	1.03902	.27769

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	4.376	.046	-.777	28	.222	.443	-.10848	.13953	-.39429	.17733
	Equal variances not assumed			-.796	26.728	.216	.433	-.10848	.13621	-.38809	.17113
M_PU_IP	Equal variances assumed	.276	.604	-1.784	26	.043	.086	-.43782	.24541	-.94226	.06662
	Equal variances not assumed			-1.756	23.054	.046	.092	-.43782	.24930	-.95348	.07783
M_PU_PPS	Equal variances assumed	.528	.474	-2.531	25	.009	.018	-.64066	.25317	-1.16207	-.11924
	Equal variances not assumed			-2.487	19.626	.011	.022	-.64066	.25764	-1.17875	-.10257
M_PU_SCND	Equal variances assumed	.307	.585	-1.192	22	.123	.246	-.53714	.45054	-1.47151	.39723
	Equal variances not assumed			-1.170	18.196	.128	.257	-.53714	.45894	-1.50059	.42630

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.38126	-.285	-1.003	.439
	Hedges' correction	.39187	-.277	-.976	.427
	Glass's delta	.43739	-.248	-.967	.479
M_PU_IP	Cohen's d	.64762	-.676	-1.435	.095
	Hedges' correction	.66708	-.656	-1.393	.092
	Glass's delta	.57954	-.755	-1.536	.049
M_PU_PPS	Cohen's d	.65731	-.975	-1.767	-.165
	Hedges' correction	.67788	-.945	-1.714	-.160
	Glass's delta	.79988	-.801	-1.606	.032
M_PU_SCND	Cohen's d	1.08817	-.494	-1.313	.336
	Hedges' correction	1.12711	-.477	-1.267	.325
	Glass's delta	1.03902	-.517	-1.343	.327

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

3. Supply uncertainty

Group Statistics

	Supply_uncertainty	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	Supply uncertainty	1	1.8333	.	.
	No supply uncertainty	29	2.0040	.38405	.07132
M_PU_IP	Supply uncertainty	1	1.8750	.	.
	No supply uncertainty	27	2.3210	.68072	.13101
M_PU_PPS	Supply uncertainty	1	2.2000	.	.
	No supply uncertainty	26	2.2904	.73648	.14444
M_PU_SCND	Supply uncertainty	1	1.2000	.	.
	No supply uncertainty	23	2.9043	1.06493	.22205

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.	.	-.437	28	.333	.665	-.17069	.39061	-.97083	.62945
	Equal variances not assumed			.	.	.	.	-.17069	.	.	.
M_PU_IP	Equal variances assumed	.	.	-.643	26	.263	.526	-.44599	.69321	-1.87091	.97893
	Equal variances not assumed			.	.	.	.	-.44599	.	.	.
M_PU_PPS	Equal variances assumed	.	.	-.120	25	.453	.905	-.09038	.75051	-1.63609	1.45532
	Equal variances not assumed			.	.	.	.	-.09038	.	.	.
M_PU_SCND	Equal variances assumed	.	.	-1.567	22	.066	.131	-1.70435	1.08783	-3.96037	.55168
	Equal variances not assumed			.	.	.	.	-1.70435	.	.	.

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
M_PU_SOP	Cohen's d	.38405	-.444	-2.437	1.556
	Hedges' correction	.39473	-.432	-2.371	1.514
	Glass's delta	.38405	-.444	-2.437	1.556
M_PU_IP	Cohen's d	.68072	-.655	-2.653	1.355
	Hedges' correction	.70118	-.636	-2.575	1.315
	Glass's delta	.68072	-.655	-2.653	1.355
M_PU_PPS	Cohen's d	.73648	-.123	-2.119	1.876
	Hedges' correction	.75954	-.119	-2.055	1.819
	Glass's delta	.73648	-.123	-2.119	1.876
M_PU_SCND	Cohen's d	1.06493	-1.600	-3.640	.473
	Hedges' correction	1.10304	-1.545	-3.514	.457
	Glass's delta	1.06493	-1.600	-3.640	.473

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

4. Detail uncertainty (# of SKUs in product portfolio)

Group Statistics

	How many different products / stock keeping units (SKU) are included in your product portfolio?	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	>= 3	17	1.9275	.30692	.07444
	< 3	13	2.0910	.45219	.12541
M_PU_IP	>= 3	15	2.4028	.70265	.18142
	< 3	13	2.1923	.64674	.17937
M_PU_PPS	>= 3	16	2.2719	.90073	.22518
	< 3	11	2.3091	.37271	.11237
M_PU_SCND	>= 3	13	3.1077	1.10940	.30769
	< 3	11	2.5091	1.04063	.31376

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p			Lower	Upper
M_PU_SOP	Equal variances assumed	3.121	.088	-1.180	28	.124	.248	-.16357	.13857	-.44743	.12028
	Equal variances not assumed			-1.122	20.076	.138	.275	-.16357	.14584	-.46772	.14057
M_PU_IP	Equal variances assumed	.555	.463	.820	26	.210	.420	.21047	.25670	-.31718	.73812
	Equal variances not assumed			.825	25.888	.208	.417	.21047	.25513	-.31406	.73500
M_PU_PPS	Equal variances assumed	1.331	.259	-.129	25	.449	.898	-.03722	.28845	-.63129	.55685
	Equal variances not assumed			-.148	21.410	.442	.884	-.03722	.25167	-.55997	.48554
M_PU_SCND	Equal variances assumed	.083	.775	1.355	22	.095	.189	.59860	.44191	-.31786	1.51506
	Equal variances not assumed			1.362	21.733	.094	.187	.59860	.43946	-.31342	1.51063

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.37611	-.435	-1.162	.300
	Hedges' correction	.38657	-.423	-1.131	.292
	Glass's delta	.45219	-.362	-1.091	.382
M_PU_IP	Cohen's d	.67742	.311	-.440	1.055
	Hedges' correction	.69777	.302	-.427	1.024
	Glass's delta	.64674	.325	-.435	1.073
M_PU_PPS	Cohen's d	.73645	-.051	-.818	.718
	Hedges' correction	.75950	-.049	-.793	.696
	Glass's delta	.37271	-.100	-.866	.671
M_PU_SCND	Cohen's d	1.07868	.555	-.270	1.368
	Hedges' correction	1.11729	.536	-.261	1.321
	Glass's delta	1.04063	.575	-.278	1.403

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

5. Shelf life (in days)

Group Statistics

	Please indicate the average shelf life of your products.	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	>= 3	25	1.9460	.36169	.07234
	< 3	5	2.2600	.38973	.17429
M_PU_IP	>= 3	22	2.1951	.64580	.13769
	< 3	6	2.7083	.66927	.27323
M_PU_PPS	>= 3	22	2.3250	.78767	.16793
	< 3	5	2.1200	.30332	.13565
M_PU_SCND	>= 3	19	2.8105	1.08418	.24873
	< 3	5	2.9200	1.27750	.57131

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.093	.763	-1.752	28	.045	.091	-.31400	.17922	-.68111	.05311
	Equal variances not assumed			-1.664	5.470	.076	.152	-.31400	.18871	-.78682	.15882
M_PU_IP	Equal variances assumed	.110	.743	-1.713	26	.049	.099	-.51326	.29954	-1.12898	.10246
	Equal variances not assumed			-1.678	7.743	.067	.133	-.51326	.30596	-1.22290	.19638
M_PU_PPS	Equal variances assumed	1.015	.323	.565	25	.288	.577	.20500	.36267	-.54194	.95194
	Equal variances not assumed			.950	17.726	.178	.355	.20500	.21587	-.24903	.65903
M_PU_SCND	Equal variances assumed	.156	.697	-.194	22	.424	.848	-.10947	.56385	-1.27882	1.05987
	Equal variances not assumed			-.176	5.615	.433	.867	-.10947	.62311	-1.65986	1.44091

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.36582	-.858	-1.837	.135
	Hedges' correction	.37600	-.835	-1.787	.131
	Glass's delta	.38973	-.806	-1.871	.331
M_PU_IP	Cohen's d	.65038	-.789	-1.710	.146
	Hedges' correction	.66992	-.766	-1.660	.141
	Glass's delta	.66927	-.767	-1.752	.276
M_PU_PPS	Cohen's d	.73203	.280	-.697	1.251
	Hedges' correction	.75495	.272	-.676	1.213
	Glass's delta	.30332	.676	-.428	1.714
M_PU_SCND	Cohen's d	1.12181	-.098	-1.082	.889
	Hedges' correction	1.16195	-.094	-1.045	.858
	Glass's delta	1.27750	-.086	-1.067	.906

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

6. Revenue (in EUR mil.)

Group Statistics

	What is the revenue of your company? (in € mil.)	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	>= 6	17	1.9235	.34576	.08386
	< 6	14	2.0893	.39557	.10572
M_PU_IP	>= 6	15	2.3583	.75721	.19551
	< 6	13	2.2436	.58602	.16253
M_PU_PPS	>= 6	15	2.3167	.88189	.22770
	< 6	12	2.2500	.49082	.14169
M_PU_SCND	>= 6	13	2.6769	1.23973	.34384
	< 6	11	3.0182	.92717	.27955

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.245	.625	-1.245	29	.112	.223	-.16576	.13315	-.43807	.10656
	Equal variances not assumed			-1.228	26.108	.115	.230	-.16576	.13494	-.44308	.11157
M_PU_IP	Equal variances assumed	2.909	.100	.443	26	.331	.661	.11474	.25902	-.41767	.64716
	Equal variances not assumed			.451	25.711	.328	.656	.11474	.25425	-.40815	.63764
M_PU_PPS	Equal variances assumed	.701	.410	.234	25	.408	.817	.06667	.28501	-.52032	.65365
	Equal variances not assumed			.249	22.624	.403	.806	.06667	.26819	-.48863	.62197
M_PU_SCND	Equal variances assumed	2.184	.154	-.751	22	.230	.460	-.34126	.45418	-1.28316	.60065
	Equal variances not assumed			-.770	21.720	.225	.450	-.34126	.44314	-1.26096	.57845

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.36892	-.449	-1.162	.271
	Hedges' correction	.37882	-.438	-1.132	.264
	Glass's delta	.39557	-.419	-1.137	.314
M_PU_IP	Cohen's d	.68354	.168	-.578	.910
	Hedges' correction	.70409	.163	-.561	.884
	Glass's delta	.58602	.196	-.555	.939
M_PU_PPS	Cohen's d	.73589	.091	-.670	.849
	Hedges' correction	.75893	.088	-.649	.823
	Glass's delta	.49082	.136	-.628	.894
M_PU_SCND	Cohen's d	1.10863	-.308	-1.112	.504
	Hedges' correction	1.14831	-.297	-1.074	.486
	Glass's delta	.92717	-.368	-1.178	.459

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

7. Number of employees

Group Statistics

	How many employees are working at your company?	N	Mean	Std. Deviation	Std. Error Mean
M_PU_SOP	>= 7	19	1.9614	.45383	.10411
	< 7	13	2.1423	.35594	.09872
M_PU_IP	>= 7	17	2.2819	.78417	.19019
	< 7	11	2.3409	.48763	.14703
M_PU_PPS	>= 7	18	2.1583	.52419	.12355
	< 7	10	2.5400	.94304	.29822
M_PU_SCND	>= 7	14	2.6286	1.12005	.29935
	< 7	10	3.1200	1.05494	.33360

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
M_PU_SOP	Equal variances assumed	.082	.776	-1.204	30	.119	.238	-.18090	.15025	-.48776	.12595
	Equal variances not assumed			-1.261	29.341	.109	.217	-.18090	.14348	-.47420	.11239
M_PU_IP	Equal variances assumed	4.453	.045	-.223	26	.413	.826	-.05905	.26524	-.60426	.48617
	Equal variances not assumed			-.246	25.988	.404	.808	-.05905	.24039	-.55319	.43510
M_PU_PPS	Equal variances assumed	1.433	.242	-1.386	26	.089	.178	-.38167	.27538	-.94772	.18439
	Equal variances not assumed			-1.182	12.165	.130	.260	-.38167	.32280	-1.08393	.32059
M_PU_SCND	Equal variances assumed	.050	.826	-1.085	22	.145	.290	-.49143	.45291	-1.43070	.44785
	Equal variances not assumed			-1.096	20.243	.143	.286	-.49143	.44821	-1.42567	.44281

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
M_PU_SOP	Cohen's d	.41744	-.433	-1.144	.284
	Hedges' correction	.42825	-.422	-1.115	.277
	Glass's delta	.35594	-.508	-1.232	.235
M_PU_IP	Cohen's d	.68547	-.086	-.844	.673
	Hedges' correction	.70607	-.084	-.819	.654
	Glass's delta	.48763	-.121	-.878	.642
M_PU_PPS	Cohen's d	.69822	-.547	-1.329	.245
	Hedges' correction	.71920	-.531	-1.290	.238
	Glass's delta	.94304	-.405	-1.189	.400
M_PU_SCND	Cohen's d	1.09388	-.449	-1.266	.378
	Hedges' correction	1.13302	-.434	-1.223	.365
	Glass's delta	1.05494	-.466	-1.293	.385

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

b) Results of Mann-Whitney U test

1. Demand uncertainty

Ranks

	Demand_uncertainty	N	Mean Rank	Sum of Ranks
M_PU_SOP	Demand uncertainty	22	16.52	363.50
	No demand uncertainty	8	12.69	101.50
	Total	30		
M_PU_IP	Demand uncertainty	20	14.68	293.50
	No demand uncertainty	8	14.06	112.50
	Total	28		
M_PU_PPS	Demand uncertainty	20	13.03	260.50
	No demand uncertainty	7	16.79	117.50
	Total	27		
M_PU_SCND	Demand uncertainty	17	12.76	217.00
	No demand uncertainty	7	11.86	83.00
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	65.500	76.500	50.500	55.000
Wilcoxon W	101.500	112.500	260.500	83.000
Z	-1.066	-.179	-1.095	-.287
Asymp. Sig. (2-tailed)	.287	.858	.273	.774
Exact Sig. [2*(1-tailed Sig.)]	.298[b]	.862[b]	.288[b]	.804[b]

a. Grouping Variable: Demand_uncertainty

b. Not corrected for ties.

2. Production uncertainty

Ranks

	Production_uncertainty	N	Mean Rank	Sum of Ranks
M_PU_SOP	Production uncertainty	14	15.21	213.00
	No production uncertainty	16	15.75	252.00
	Total	30		
M_PU_IP	Production uncertainty	13	11.50	149.50
	No production uncertainty	15	17.10	256.50
	Total	28		
M_PU_PPS	Production uncertainty	14	10.43	146.00
	No production uncertainty	13	17.85	232.00
	Total	27		
M_PU_SCND	Production uncertainty	10	10.15	101.50
	No production uncertainty	14	14.18	198.50
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	108.000	58.500	41.000	46.500
Wilcoxon W	213.000	149.500	146.000	101.500
Z	-.168	-1.802	-2.463	-1.381
Asymp. Sig. (2-tailed)	.867	.072	.014	.167
Exact Sig. [2*(1-tailed Sig.)]	.886[b]	.072[b]	.014[b]	.172[b]

a. Grouping Variable: Production_uncertainty

b. Not corrected for ties.

3. Supply uncertainty

Ranks

	Supply_uncertainty	N	Mean Rank	Sum of Ranks
M_PU_SOP	Supply uncertainty	1	11.50	11.50
	No supply uncertainty	29	15.64	453.50
	Total	30		
M_PU_IP	Supply uncertainty	1	8.00	8.00
	No supply uncertainty	27	14.74	398.00
	Total	28		
M_PU_PPS	Supply uncertainty	1	13.50	13.50
	No supply uncertainty	26	14.02	364.50
	Total	27		
M_PU_SCND	Supply uncertainty	1	1.00	1.00
	No supply uncertainty	23	13.00	299.00
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	10.500	7.000	12.500	.000
Wilcoxon W	11.500	8.000	13.500	1.000
Z	-.467	-.807	-.065	-1.668
Asymp. Sig. (2-tailed)	.641	.420	.948	.095
Exact Sig. [2*(1-tailed Sig.)]	.733[b]	.571[b]	.963[b]	.083[b]

a. Grouping Variable: Supply_uncertainty

b. Not corrected for ties.

4. Detail uncertainty (# of SKUs in product portfolio)

Ranks

	Detail uncertainty	N	Mean Rank	Sum of Ranks
M_PU_SOP	No detail uncertainty	13	17.77	231.00
	Detail uncertainty	17	13.76	234.00
	Total	30		
M_PU_IP	No detail uncertainty	13	13.15	171.00
	Detail uncertainty	15	15.67	235.00
	Total	28		
M_PU_PPS	No detail uncertainty	11	15.41	169.50
	Detail uncertainty	16	13.03	208.50
	Total	27		
M_PU_SCND	No detail uncertainty	11	10.27	113.00
	Detail uncertainty	13	14.38	187.00
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	81.000	80.000	72.500	47.000
Wilcoxon W	234.000	171.000	208.500	113.000
Z	-1.247	-.809	-.776	-1.425
Asymp. Sig. (2-tailed)	.212	.419	.437	.154
Exact Sig. [2*(1-tailed Sig.)]	.229[b]	.440[b]	.451[b]	.167[b]

a. Grouping Variable: Detail uncertainty

b. Not corrected for ties.

5. Shelf life (in days)

Ranks

	Shelf life	N	Mean Rank	Sum of Ranks
M_PU_SOP	Up to 30	5	21.40	107.00
	More than 30	25	14.32	358.00
	Total	30		
M_PU_IP	Up to 30	6	18.75	112.50
	More than 30	22	13.34	293.50
	Total	28		
M_PU_PPS	Up to 30	5	11.20	56.00
	More than 30	22	14.64	322.00
	Total	27		
M_PU_SCND	Up to 30	5	12.80	64.00
	More than 30	19	12.42	236.00
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	33.000	40.500	41.000	46.000
Wilcoxon W	358.000	293.500	56.000	236.000
Z	-1.658	-1.432	-.887	-.107
Asymp. Sig. (2-tailed)	.097	.152	.375	.915
Exact Sig. [2*(1-tailed Sig.)]	.108[b]	.157[b]	.411[b]	.945[b]

a. Grouping Variable: Shelf life

b. Not corrected for ties.

6. Revenue (in EUR mil.)

Ranks

	Revenue	N	Mean Rank	Sum of Ranks
M_PU_SOP	Up to 249	14	19.11	267.50
	More than 249	17	13.44	228.50
	Total	31		
M_PU_IP	Up to 249	13	13.85	180.00
	More than 249	15	15.07	226.00
	Total	28		
M_PU_PPS	Up to 249	12	14.96	179.50
	More than 249	15	13.23	198.50
	Total	27		
M_PU_SCND	Up to 249	11	13.82	152.00
	More than 249	13	11.38	148.00
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	75.500	89.000	78.500	57.000
Wilcoxon W	228.500	180.000	198.500	148.000
Z	-1.745	-.393	-.570	-.843
Asymp. Sig. (2-tailed)	.081	.694	.569	.399
Exact Sig. [2*(1-tailed Sig.)]	.084[b]	.717[b]	.581[b]	.424[b]

a. Grouping Variable: Revenue

b. Not corrected for ties.

7. **Number of employees**

Ranks

	Employees	N	Mean Rank	Sum of Ranks
M_PU_SOP	Up to 499	13	19.38	252.00
	More than 499	19	14.53	276.00
	Total	32		
M_PU_IP	Up to 499	11	14.59	160.50
	More than 499	17	14.44	245.50
	Total	28		
M_PU_PPS	Up to 499	10	16.00	160.00
	More than 499	18	13.67	246.00
	Total	28		
M_PU_SCND	Up to 499	10	14.15	141.50
	More than 499	14	11.32	158.50
	Total	24		

Test Statistics[a]

	M_PU_SOP	M_PU_IP	M_PU_PPS	M_PU_SCND
Mann-Whitney U	86.000	92.500	75.000	53.500
Wilcoxon W	276.000	245.500	246.000	158.500
Z	-1.452	-.047	-.729	-.970
Asymp. Sig. (2-tailed)	.146	.962	.466	.332
Exact Sig. [2*(1-tailed Sig.)]	.158[b]	.963[b]	.494[b]	.341[b]

a. Grouping Variable: Employees

b. Not corrected for ties.

Appendix 7: Survey Results SCND Software

a) Familiarity

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
How familiar are you with software/software modules for supply chain network design?	0.00%	10.00%	26.67%	46.67%	16.67%

b) Perceived usefulness of functions

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Determination of product strategy – includes number and main characteristics of products as well as markets to be served	12.50%	37.50%	12.50%	25.00%	12.50%
Determination of manufacturing strategy – includes number and location of plants, sourcing strategy, investment decisions and supplier selection	12.50%	33.33%	25.00%	16.67%	12.50%
Determination of logistics strategy – includes number, locations and echelons of distribution centers, sourcing strategy and investment decisions	29.17%	29.17%	4.17%	29.17%	8.33%
Determination of procurement strategy – includes number of suppliers and selection of suppliers	12.50%	33.33%	25.00%	16.67%	12.50%
Determination of investment/divestment decisions – includes in-/outsourcing, acquisitions/mergers and new technology introduction	12.50%	29.17%	16.67%	25.00%	16.67%

c) Barriers to software implementation

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	15.79%	26.32%	52.63%	0.00%	5.26%
There is a lack of expertise to use the software.	31.58%	15.79%	31.58%	15.79%	5.26%
There is a lack of data quality to use the software.	21.05%	26.32%	26.32%	21.05%	5.26%
There is a lack of time for an implementation project.	15.79%	52.63%	26.32%	0.00%	5.26%
Specific company requirements cannot be covered.	0.00%	5.26%	63.16%	26.32%	5.26%
Required interfaces to other systems are too expensive/complex to set up and to maintain.	15.79%	10.53%	52.63%	15.79%	5.26%
The functions are not relevant for our business model.	5.26%	21.05%	52.63%	10.53%	10.53%

Appendix 8: Survey Results S&OP Software

a) Familiarity

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
How familiar are you with software/software modules for sales & operations planning?	2.94%	20.59%	44.12%	20.59%	11.76%

b) Coverage of functions

	Extensively covered	Well covered	Partly covered	Not covered at all
Statistical forecasting – assist the planner in making estimations derived from historical data	0.00%	69.23%	23.08%	7.69%
Incorporation of judgmental factors – to correct and improve statistical forecast (e.g. by consensus of experts)	0.00%	16.67%	50.00%	33.33%
Collaborative/consensus-based decision process – assures that input for the demand planning process can be collected from all involved departments	30.77%	30.77%	30.77%	7.69%
Accuracy measurement – accuracy measures such as the Mean Absolute Percentage Error (MAPE) or the Mean Absolute Deviation (MAD) can be used to track and evaluate forecast accuracy	15.38%	46.15%	23.08%	15.38%
Creation of unrestricted operations plan – calculation of net demand considering inventory and comparison of production quantities with available capacities	15.38%	30.77%	30.77%	23.08%
Bottleneck resolution – in case of bottlenecks automated generation of a feasible plan (e.g. by building up inventory or scheduling additional shifts)	0.00%	38.46%	46.15%	15.38%

c) Perceived usefulness of functions

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Statistical forecasting – assist the planner in making estimations derived from historical data	9.09%	72.73%	9.09%	9.09%	0.00%
Incorporation of judgmental factors – to correct and improve statistical forecast (e.g. by consensus of experts)	11.11%	33.33%	33.33%	11.11%	11.11%
Collaborative/consensus-based decision process – assures that input for the demand planning process can be collected from all involved departments	58.33%	33.33%	8.33%	0.00%	0.00%
Accuracy measurement – accuracy measures such as the Mean Absolute Percentage Error (MAPE) or the Mean Absolute Deviation (MAD) can be used to track and evaluate forecast accuracy	10.00%	60.00%	30.00%	0.00%	0.00%
Creation of unrestricted operations plan – calculation of net demand considering inventory and comparison of production quantities with available capacities	40.00%	50.00%	10.00%	0.00%	0.00%
Bottleneck resolution – in case of bottlenecks automated generation of a feasible plan (e.g. by building up inventory or scheduling additional shifts)	20.00%	30.00%	40.00%	10.00%	0.00%

d) Implementation success

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The cost of the sales & operations planning software was significantly higher than the expected budgets.	0.00%	11.11%	33.33%	55.56%	0.00%
The implementation project for the sales & operations planning software took significantly longer than expected.	0.00%	45.45%	18.18%	36.36%	0.00%
The performance of the sales & operations planning software is significantly below the expected level.	0.00%	11.11%	0.00%	66.67%	22.22%
The anticipated benefits of the sales & operations planning software have not been materialized.	0.00%	0.00%	11.11%	44.44%	44.44%

e) Barriers to software implementation

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	20.00%	20.00%	60.00%	0.00%	0.00%
There is a lack of expertise to use the software.	20.00%	20.00%	40.00%	20.00%	0.00%
There is a lack of data quality to use the software.	20.00%	20.00%	20.00%	0.00%	40.00%
There is a lack of time for an implementation project.	0.00%	40.00%	40.00%	20.00%	0.00%
Specific company requirements cannot be covered.	0.00%	20.00%	60.00%	20.00%	0.00%
Required interfaces to other systems are too expensive/complex to set up and to maintain.	0.00%	20.00%	40.00%	40.00%	0.00%
The functions are not relevant for our business model.	20.00%	0.00%	40.00%	20.00%	20.00%

Appendix 9: Survey Results IP Software

a) Familiarity

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
How familiar are you with software/software modules for inventory planning?	9.38%	18.75%	59.38%	6.25%	6.25%

b) Coverage of functions

	Extensively covered	Well covered	Partly covered	Not covered at all
Inventory management – includes features such as product categorization, product history and stock inquiries	16.67%	66.67%	16.67%	0.00%
Inventory level projection – includes calculation and display of accurate inventory levels for future periods	8.33%	33.33%	58.33%	0.00%
Inventory optimization – includes determination of optimal size of stocks, safety stock, reorder point, supply period, service level etc.	0.00%	33.33%	41.67%	25.00%
Order planning – includes features such as replenishment suggestions, creation of an order plan and upload of order proposal data to the connected purchasing system	8.33%	41.67%	33.33%	16.67%
Inventory tracking – includes features such as product tracking and audit trail	0.00%	41.67%	33.33%	25.00%
Stock-out and overstock alerts – includes alerts in case any product is in short supply, or in excess	9.09%	45.45%	45.45%	0.00%
Transfer management – includes features such as multi-location tracking, order picking, kitting and product bundling	8.33%	25.00%	16.67%	50.00%
Value added services – includes features such as labelling and manufacturing of displays	8.33%	25.00%	16.67%	50.00%

c) Perceived usefulness of functions

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Inventory management – includes features such as product categorization, product history and stock inquiries	18.18%	54.55%	9.09%	18.18%	0.00%
Inventory level projection – includes calculation and display of accurate inventory levels for future periods	27.27%	54.55%	18.18%	0.00%	0.00%
Inventory optimization – includes determination of optimal size of stocks, safety stock, reorder point, supply period, service level etc.	18.18%	45.45%	18.18%	18.18%	0.00%
Order planning – includes features such as replenishment suggestions, creation of an order plan and upload of order proposal data to the connected purchasing system	18.18%	36.36%	9.09%	27.27%	9.09%
Inventory tracking – includes features such as product tracking and audit trail	10.00%	30.00%	40.00%	20.00%	0.00%
Stock-out and overstock alerts – includes alerts in case any product is in short supply, or in excess	27.27%	54.55%	0.00%	18.18%	0.00%
Transfer management – includes features such as multi-location tracking, order picking, kitting and product bundling	18.18%	18.18%	9.09%	36.36%	18.18%
Value added services – includes features such as labelling and manufacturing of displays	18.18%	36.36%	0.00%	18.18%	27.27%

d) Implementation success

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The cost of the inventory planning software was significantly higher than the expected budgets.	0.00%	16.67%	33.33%	33.33%	16.67%
The implementation project for the inventory planning software took significantly longer than expected.	0.00%	28.57%	42.86%	28.57%	0.00%
The performance of the inventory planning software is significantly below the expected level.	0.00%	0.00%	28.57%	28.57%	42.86%
The anticipated benefits of the inventory planning software have not been materialized.	0.00%	14.29%	0.00%	57.14%	28.57%

e) Barriers to software implementation

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	16.67%	16.67%	66.67%	0.00%	0.00%
There is a lack of expertise to use the software.	16.67%	16.67%	50.00%	16.67%	0.00%
There is a lack of data quality to use the software.	16.67%	0.00%	50.00%	33.33%	0.00%
There is a lack of time for an implementation project.	0.00%	66.67%	33.33%	0.00%	0.00%
Specific company requirements cannot be covered.	0.00%	33.33%	33.33%	33.33%	0.00%
Required interfaces to other systems are too expensive/complex to set up and to maintain.	16.67%	16.67%	50.00%	0.00%	16.67%
The functions are not relevant for our business model.	0.00%	16.67%	66.67%	16.67%	0.00%

Appendix 10: Survey Results PP&S Software

a) Familiarity

	Extremely familiar	Very familiar	Moderately familiar	Slightly familiar	Not familiar at all
How familiar are you with software/software modules for production planning & scheduling?	6.67%	30.00%	50.00%	10.00%	3.33%

b) Coverage of functions

	Extensively covered	Well covered	Partly covered	Not covered at all
Dynamic lot-sizing – definition of quantity of an item to manufacture in a single production run	14.29%	21.43%	14.29%	50.00%
Automated scheduling – algorithm-based scheduling and sequencing of production orders	0.00%	28.57%	42.86%	28.57%
Manual scheduling – to correct and improve production schedules by input of dispatchers etc.	35.71%	57.14%	7.14%	0.00%
Shop floor control – comprises methods and systems to prioritize, track, and report against production orders and schedules	21.43%	42.86%	35.71%	0.00%
Rescheduling of orders – enabled by drag & drop functionality in an interactive planning board	14.29%	35.71%	28.57%	21.43%

c) Perceived usefulness of functions

	Extremely useful	Very useful	Moderately useful	Slightly useful	Not useful at all
Dynamic lot-sizing – definition of quantity of an item to manufacture in a single production run	15.38%	23.08%	23.08%	23.08%	15.38%
Automated scheduling – algorithm-based scheduling and sequencing of production orders	16.67%	41.67%	33.33%	8.33%	0.00%
Manual scheduling – to correct and improve production schedules by input of dispatchers etc.	23.08%	61.54%	15.38%	0.00%	0.00%
Shop floor control – comprises methods and systems to prioritize, track, and report against production orders and schedules	7.69%	69.23%	15.38%	7.69%	0.00%
Rescheduling of orders – enabled by drag & drop functionality in an interactive planning board	15.38%	76.92%	0.00%	0.00%	7.69%

d) Implementation success

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The cost of the production planning & scheduling software was significantly higher than the expected budgets.	12.5%	25.0%	25.0%	25.0%	12.5%
The implementation project for the production planning & scheduling software took significantly longer than expected.	0.0%	37.5%	25.0%	37.5%	0.0%
The performance of the production planning & scheduling software is significantly below the expected level.	0.0%	12.5%	37.5%	37.5%	12.5%
The anticipated benefits of the production planning & scheduling software have not been materialized.	0.0%	0.0%	25.0%	62.5%	12.5%

e) Barriers to software implementation

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The return on investment is low.	0.00%	20.00%	60.00%	0.00%	20.00%
There is a lack of expertise to use the software.	40.00%	0.00%	40.00%	0.00%	20.00%
There is a lack of data quality to use the software.	20.00%	20.00%	40.00%	0.00%	20.00%
There is a lack of time for an implementation project.	0.00%	40.00%	40.00%	0.00%	20.00%
Specific company requirements cannot be covered.	0.00%	0.00%	60.00%	20.00%	20.00%
Required interfaces to other systems are too expensive/complex to set up and to maintain.	20.00%	20.00%	40.00%	0.00%	20.00%
The functions are not relevant for our business model.	40.00%	0.00%	40.00%	20.00%	0.00%

Appendix 11: Frequency of Codes in Interview Responses

Themes	Codes	Food producers	Software vendors	Consultants	Total
System requirements for APS adoption	Ease of use	2	5	6	13
	Functionalities	3	3	7	13
	Technical integration with ERP system	1	3	6	10
	References			2	2
	Customer support		1		1
	Data security		1		1
Organisational requirements for APS adoption	Expertise	1	4	6	11
	Company size		5	5	10
	Data quality		5	3	8
	Management support	2	4	2	8
	SCM processes	2	2	3	7
	Technical integration with APS		1	2	3
Drivers for APS adoption	Specific use cases		5	6	11
	SC complexity	2	5	2	9
	Review of SCM practices	1	1		2
	Job attractiveness		1		1
	Change of ERP system		1		1
Barriers to APS adoption	Lack of business case	2	5	6	13
	Lack of human resources	1	5	6	12
	Lack of management support	2	3	1	6
	Complexity of interfaces			2	2
	Lack of data quality	1			1
Implementation projects	Ensure availability of resources		5	6	11
	Maintain management support		4	3	7

	Highlight process requirements		3	3	6
	Ensure high data quality		3	2	5
	Develop strategic view for targeted software adoption		2	2	4