food industry : a systematic literature review. / Stave, David; van der Meer, Robert; Lutke Entrup, Matthias; Ali Agha, Mouhamad Shaker. 2020. Paper presented at Hamburg International Conference on Logistics 2020, Hamburg, Germany.

Supply chain planning in the food industry

Abstract

Purpose: Advanced Planning Systems (APS) can contribute to improved decision-making and enhanced efficiency along complex food supply chains. This paper presents a systematic literature review of supply chain planning (SCP) in the food industry. In particular, the literature on three increasingly important planning tasks supported by APS is examined, namely Supply Chain Network Design, Sales & Operations Planning and Production Planning & Scheduling.

Methodology: A literature review is conducted by systematically collecting the existing literature published between 1998 and 2020 and classifying it based on three planning tasks supported by APS modules (Supply Chain Network Design, Sales & Operations Planning and Production Planning & Scheduling). Furthermore, research papers are categorized according to the product under consideration, geographic region and method.

Findings: Multiple models for SCP practices have been developed. The modelling literature is fragmented around specific challenges faced in food supply chains. Empirical literature including case studies on the implementation of APS is sparse. The findings suggest that developed models for the three examined planning tasks are only implemented to a limited extent in practice.

Originality: This paper focuses on three planning tasks that are of increasing relevance for the food industry. The literature review can help practitioners within the food industry to get insights regarding the opportunities offered by the three software modules examined in this paper. Further research should be conducted in these areas to make literature on SCP more practically relevant for managers.

1. Introduction

Supply chain management (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, Farahani, & Grunow, 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. Consumer attitudes are constantly changing, leading to mass customization and a growing amount of product variants (Trienekens, Wognum, Beulens, & van der Vorst, Jack GAJ, 2012). Consumer demand fluctuates depending on weather and other factors. Therefore, supply chain planning (SCP) is essential for food companies to retain an overview of the supply chain (Ivert et al., 2015). Planning problems faced by food companies can be expressed in mathematical models and solved by dedicated software tools. Advanced planning systems (APS) support long-term, mid-term and short-term decision-making and ensure efficient use of resources along the supply chain (Neumann, Schwindt, & Trautmann, 2002). 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 & Ivert, 2015; Vlckova & Patak, 2011). Likewise, Jonsson and Holmström (2016) diagnose a gap between research and practice in the literature of SCP.

Corresponding to the complexity of food supply chains and the resulting need for SCP, the purpose of this paper is to improve the understanding of SCP in a specific context, namely the food industry. To achieve this aim, the study seeks to systematically review the modelling research for SCP in food companies as well as the literature on APS implementation to support SCP practices. The literature review particularly considers the context of application of proposed methods for SCP, indicating the practical relevance of research. This should provide insights into the opportunities of SCP within different food supply chains. In addition, it is examined to what extent the use of APS supporting long-term, mid-term and short-term decisions is covered and facilitated by research. Research on APS implementation is critical as effective SCP requires support by specific software tools. In particular, the study will focus on three different planning tasks that become increasingly relevant for food companies, namely supply chain network design, sales & operations planning (S&OP), and production planning & scheduling. 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 emphasizing sustainability and food quality.

The remainder of this paper is structured as follows: In the next section APS is introduced to the reader and it is argued why the three mentioned modules are of increasing relevance for the food industry. Subsequently, 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 three planning tasks and the application context is presented. Thereafter, research papers on APS implementation are investigated. The literature review is followed by a discussion. Lastly, findings are summarized in the conclusion and recommendations for further research are provided.

2. Advanced planning systems

The application of APS can address the complexity of food supply chains and conflicting objectives faced by managers of the industry. APS comprise different software modules involving different functionalities and planning tasks, respectively. Figure 1 gives an overview of software modules covered by APS. The framework distinguishes between software modules based on the respective dimensions of 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 synchronized. Inventory planning is also carried out at this level. At the operational level, the mid-term plans are broken down into concrete 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 are identified, assessed and reported by means of a risk management module. In addition, software solutions in the area of supply chain visibility and business analytics can enhance transparency along the supply chain and visualize the performance of the entire supply chain using selected KPIs.

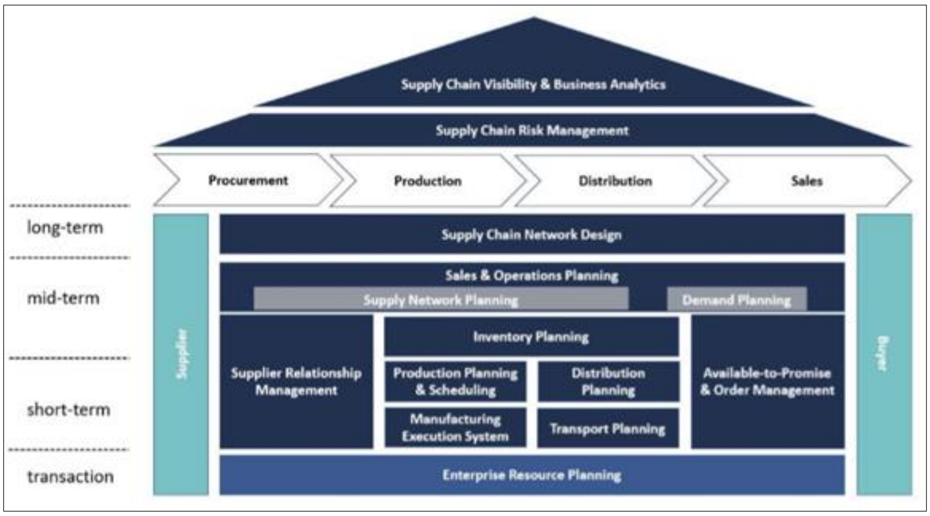

Figure 1: Supply chain planning & navigation framework

By means of these tools, mathematical models of operations research for long-term, mid-term and short-term SCP can be speedily solved. Moreover, APS ensure increased flexibility in case of deviations from original plans and capture interdependencies of planning decisions (Stadtler & Kilger, 2002).

The present paper focuses on three APS modules, namely supply chain network design, S&OP, and production planning & scheduling. Typical functionalities of the respective modules are depicted in Table 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 & Villalobos, 2009). Consequently, decisions regarding the physical structure of the supply chain are essential for food companies.

Responding 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 & Vlckova, 2012). The process can be supported by either separate demand and supply network planning modules or an integrated version.

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

Module	Functionalities
Supply chain network design	• 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 investment/divestment decisions: Includes in-/outsourcing, acquisitions/mergers and new technology introduction.
Sales & operations planning	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. consensus of experts, independent inputs of salespeople). • 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. Operations 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, scheduling additional shifts etc.).
Production planning & scheduling	• 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 production managers 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.

Table 1: Functionalities of APS modules for supply chain network design, sales & operations planning and production planning & scheduling (Lütke Entrup, 2005)

3. Research approach

A systematic literature review is conducted to better understand the efforts to support more efficient food supply chains through supply chain network design, S&OP and production planning & scheduling. The review approach pursued in this paper comprises four sequential steps (Mayring, 2003). Firstly, the research papers are collected. Studies for review are obtained through Scopus and Google Scholar databases, and snowballing of citations in relevant papers. Keywords used are “food industry”, “supply chain planning”, “advanced planning systems”, “supply chain network design”, “strategic network planning", "sales & operations planning", "S&OP", "demand planning", "supply network planning", "production planning & scheduling", "production planning" and "production scheduling". Studies published between 1998 and 2020 in peer-reviewed journals are considered.[1] Only papers addressing SCP practices of food companies that can be associated with supply chain network design, S&OP and production planning & scheduling are selected. Secondly, collected studies are examined based on year of publication, author, and publishing journal. Thirdly, studies are categorized according to the three mentioned fields of SCP. Lastly, the individual modelling approaches for SCP of the collected research papers are presented. Characteristics of the targeted food supply chain, including the product and country under consideration, are depicted to indicate the practical relevance of the selected modelling research. Moreover, the methods underlying the respective models are 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 specialized software modules. Overall, this review of customized modelling approaches for SCP within food companies and of research on APS implementation as an enabler of SCP is expected to give a useful indication of the current state of literature regarding SCP in the food industry.

4. Research segmentation and overview

4.1 Distribution of papers over the years

The final list of papers that could be identified through Scopus and Google Scholar comprises 77 peer-reviewed research papers that deal with SCP within the food industry supporting either of the three planning tasks under consideration (see Figure 2). In this paper, only a part of the selected papers will be presented as an illustrative example; the full list can be requested from the authors. In total 22 studies can be categorized as belonging to the domain of supply chain network design. 17 papers are associated with mid-term SCP supporting the S&OP process. The majority of the identified literature, comprising 38 research papers, is aimed at enhancing production planning & scheduling. Overall, there was a growing interest in this kind of SCP research till 2015, with a small decline in published research papers in the past five years.

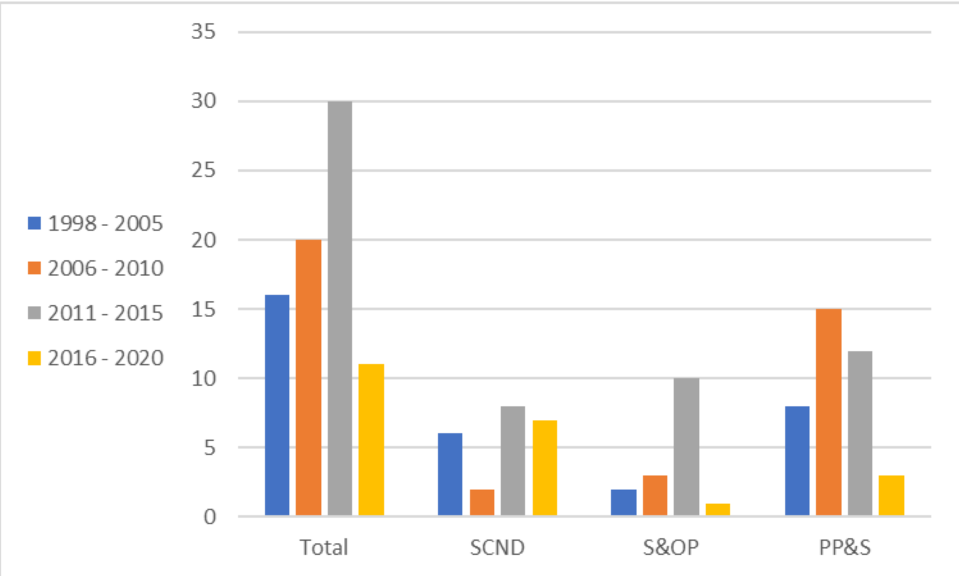

Figure 2: Distribution of papers over time

[1] In 1998 SAP APO was introduced as software for integrated business planning

4.2 Contributions classified by author

In total 176 scholars have contributed to the 77 selected research papers for this literature review. Akkerman, Bilgen and Grunow are among the top contributing authors to the domain of SCP in the food industry (see Figure 3). While Akkerman can be associated with five papers, Bilgen and Grunow are involved in four studies published in peer-reviewed academic journals.

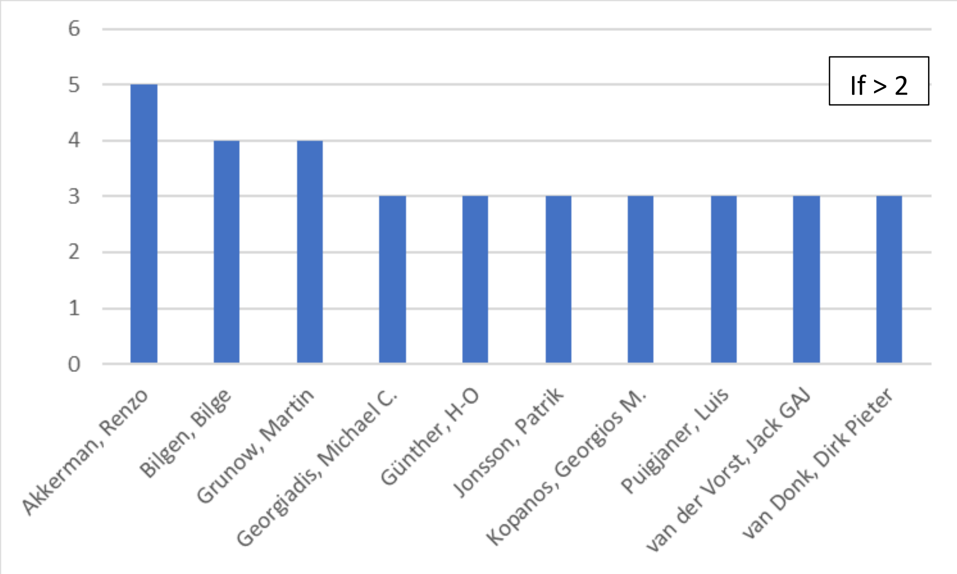

Figure 3: Contributions classified by author

4.3 Contributions classified by journal

Research papers are selected from 29 different academic journals. Among the various journals, International Journal of Production Research, International Journal of Production Economics and European Journal of Operational Research provided the most contributions in the focused areas of SCP for the food industry (see Figure 4).

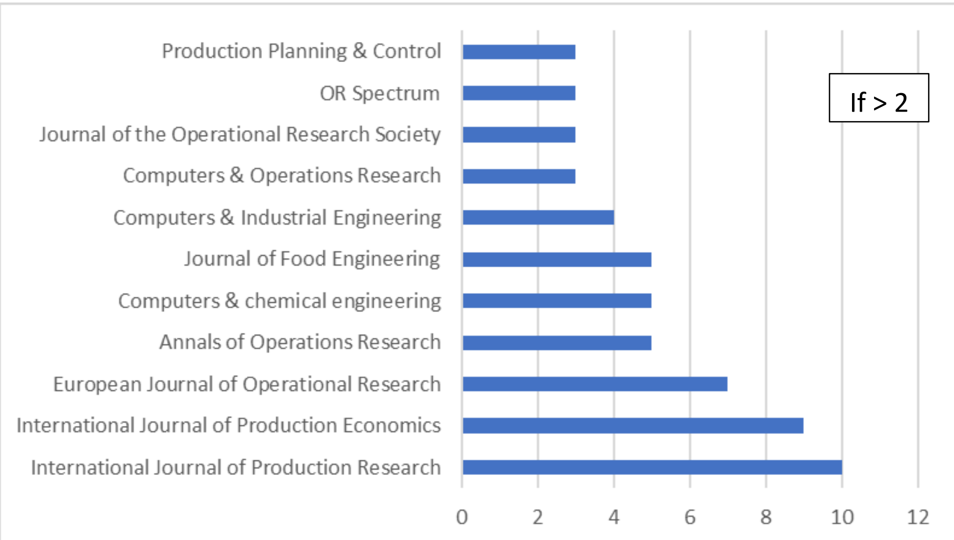

Figure 4: Contributions classified by academic journal

5. Classification based on problem context

5.1 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). Most of these scholars elaborated models using mixed integer linear programming (MILP) methods to optimize the configuration of the supply chain. Hosseini-Motlagh, Samani, and Saadi (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, van Beek, van der Vorst, Jack GAJ, and Tacke (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. Their approach ensures that the quality requirements of customers are met while overall transportation costs and carbon emissions of vehicles are reduced. According to these authors, the model can be applied to various kinds of perishable products such as fruit, vegetables or dairy products. Similarly, Mohammed and Wang (2017) investigated a three-echelon meat supply chain and presented a model that involves multiple objectives. The model aims to minimize transportation costs, the number of vehicles needed as well as delivery time, while the optimal number of farms and abattoirs is identified. Further methods have been developed by scholars to optimize material flow within a supply chain network. The model formulated by Khalili-Damghani, Tavana, and Amirkhan (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. They emphasize that supply chains need to be analysed and configured depending on the demand situation of a certain product. 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, Creazza, Dallari, and Melacini (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.

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

Table 2: Example models for supply chain network design

5.2 Sales & Operations Planning

Academics have also developed modelling approaches for sales & operations planning in the food industry (see Table 3). In their research Nemati, Madhoshi, and Ghadikolaei (2017) compared fully integrated, 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 maximize 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.

Two basic approaches for demand forecasting are time-series-analysis and causal models. 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 & Kilger, 2002). Various researchers compared different forecasting methods at companies within the food industry. Barbosa, Christo, and Costa (2015) applied three different exponential smoothing methods (simple exponential smoothing method, Holt's method & Holt-Winters method) to a company producing pasta and sausages in Brazil. Based on the MAPE (mean absolute percentage error) their study indicates that the Holt-Winters method is most effective in forecasting products with trend and seasonality patterns.

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, Akkerman, and Grunow (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 main objective of the model is to maximize revenues. Perishability of products is taken into account by a loss function and by limiting the storage time. Higgins, Beashel, and Harrison (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 storage constraints of the individual ports. The authors argue that production and shipping costs could be significantly reduced based on the proposed model. Takey and Mesquita (2006) studied production and inventory processes with high seasonal demand of a Brazilian ice cream manufacturer. The modelling approach that they developed defines monthly production plans and work-force requirements. The aggregate plans can be transferred into short-term production plans. Further improvements in demand forecasting leading to inventory reductions are advocated by the authors. Furthermore, Ioannou (2005) reports on a reorganization project in which the distribution network of a Greek sugar producer could be optimized. Newly developed transportation models resulted in essential savings for the company. The method by Sel, Bilgen, Bloemhof-Ruwaard, and van der Vorst, Jack GAJ (2015) supports integrated tactical and operational decision-making for production planning and scheduling. A heuristic is proposed to decompose mid-term planning into short-term scheduling of yoghurt production. Their approach is validated by illustrative case studies.

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

Rong et al. (2011)	Bell peppers	-	MILP
Higgins et al. (2006)	Sugar	Australia	MILP & heuristics
Takey and Mesquita (2006)	Ice cream	Brazil	LP
Ioannou (2005)	Sugar	Greece	LP

Table 3: Example models for S&OP/demand planning/supply network planning

5.3 Production planning & scheduling

Several modelling approaches have also been developed for production planning & scheduling of food products (see Table 4). Doganis and Sarimveis (2008), for instance, formulated a method to optimize 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 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, Günther, van Beek, Grunow, and Seiler (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, Akkerman, van Donk, and Grunow (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, Günther, and Almada-Lobo (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, Verbeeck, Verstraete, Berghe, and Causmaecker (2012) developed a specialized 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.

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

Table 4: Example models for production planning & scheduling

5.4 Implementation of Advanced Planning Systems

The literature mentioned above covers multiple mathematical models that have been developed targeted towards 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 5).

A few studies have investigated the utilization 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 utilizing 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. They found a positive effect on supply chain performance from the application of planning software for master production scheduling. 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. Zago and Mesquita (2015) conducted a case study at a Brazilian dairy company to assess 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, Keegan, Vigus, and Wood (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, Kjellsdotter, and Rudberg (2007) conducted explorative case studies of three companies using APS software, including two companies from the food industry. One of them, a producer of vegetable oils and fats, implemented a software module for supply chain network design after a merger to analyse the utilization 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 as a plan-related problem. Various propositions regarding the causes of such problems are provided by the authors (Ivert & Jonsson, 2011).

Paper	**Method**	**Objective**
Jonsson and Ivert (2015)	Survey among Swedish manufacturing companies from different industries (including food & beverage)	Determine the impact of different master production scheduling 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 master production scheduling
Brown et al. (2001)	Case study of a company producing cereals and convenience food	Examine the effects of using a software supporting tactical and operational SCP

Table 5: Research papers on APS implementation in the food industry

6. Discussion

This literature review has shown that multiple mathematical models of operations research have been developed and customized to complex planning problems within food supply chains. Academics have formulated diverse modelling approaches to support decisions relating to supply chain network design, S&OP and production planning & scheduling, taking account of the specifics in different food sectors around the world. The methods are intended to help supply chain managers 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 (Amorim et al., 2012; Omar & Teo, 2007). The applicability of mathematical models is emphasized by scholars. This corresponds to the call by various academics to conduct more practical relevant research (Graves, 2009; Toffel, 2016). While most methods are validated by real data, the implementation in practice of a large part of modelling approaches remains vague.

By applying dedicated software tools, the models can be applied within a reduced planning time. APS ensure increased flexibility in case of deviations from original plans and capture interdependencies of planning decisions (Stadtler & Kilger, 2002). 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 aimed at supply chain efficiency, such as ERP systems (Hong & Kim, 2002; Momoh, Roy, & Shehab, 2010). Apart from that, the implementation of ERP systems is also different from APS implementation (Wiers, 2002). Existing research predominantly reports on the benefits of APS (e.g. lower inventory levels) (Zago & Mesquita, 2015). Those papers examining whether APS modules have actually been implemented observe either no utilization or less advanced methods of SCP (Jonsson & Ivert, 2015; Vlckova & Patak, 2011). Moreover, the few case studies on APS implementation are rather focused on tactical SCP. Only two research papers could be identified that deal with the implementation of software tools for either short-term or long-term SCP. Likewise, research does not consider the effects of integrated planning by using multiple APS modules.

This literature review has revealed the great effort that has been committed by researchers in the domain of operations research to capture the complexity of food supply chains. This is reflected by the multitude of customized modelling approaches that have been developed to support SCP. Such complex models mostly require specific software (such as APS) to be solved. Research on the implementation of SCP enabled by specific software tools is rare, however. Therefore, further research needs to be done to explore SCP practices of food companies in practice and to evaluate how supply chains can be effectively supported by APS modules. This corresponds to the propositions of Fisher (2007), who encouraged academics to conduct more empirical research within the domain of operations management. It is argued that, based on empirical observations, hypotheses could be developed and validated to give practical advice for enhanced operations. Likewise, future studies on SCP may empirically investigate the implementation of information technology to support different planning tasks. Considering the complexity of food supply chains comprising fluctuating demand, growing product variety and food characteristics such as limited shelf-life that pose enormous challenges to supply chain managers, research on APS implementation could improve decision-making in food companies and thereby increase its practical relevance, as requested by Toffel (2016).

7. Concluding remarks

The inherent complexity of food supply chains, including the perishability of products, requires effective decision-support for managers. APS constitute the essential means to enhance operational efficiency along the supply chain. Moreover, sophisticated SCP contributes to ecological benefits, such as reduced carbon emissions and food waste. Multiple models for SCP have been conceptualized for different planning tasks, while studies on the implementation of the proposed methods, and in particular of APS, are rare. Therefore, more research needs to be conducted on APS to empower companies to capitalise on the digitalization of their supply chain.

This literature review is limited to two databases. Consequently, this paper may not cover all of the modelling research targeted to support food companies in the areas of supply chain design, S&OP and production planning & scheduling. Moreover, the categorization of mathematical models into different areas of SCP can be challenging, as transitions between planning tasks in terms of planning horizon and objectives are fluid. Nonetheless, it can be expected that this did not significantly affect the objective of this paper to create an accurate picture of the literature on SCP in the food industry and its practical relevance.

Future research needs to pursue a more empirical approach to the implementation of APS in support of different planning tasks. Based on that approach, new insights could be obtained. Firstly, preconditions for food companies to effectively implement APS modules could be determined. Software tools may require certain data or interfaces to other systems. Secondly, requirements to specific APS modules to better suit the needs of the food industry could be determined. A survey among managers in the food industry could provide new insights regarding the perspective of companies on the benefit of software tools for SCP. Thirdly, an investigation of the relationship between supply chain complexity and the impact on supply chain performance by APS modules provides further interesting research opportunities. Thus, the benefit of certain functions of software tools for SCP may be related to the shelf-life of food products or the amount of stock keeping units that need to be coordinated in a supply chain. Thereby, the understanding of SCP and of an effective use of APS can be continuously strengthened in order to facilitate supply chain management and ultimately enhance the efficiency of food supply chains.

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