The impact of supply uncertainty on supply chain planning processes: reflections from a whitefish case study

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Abstract

This paper investigates supply uncertainty and supply chain planning (SCP) in a white-fish supply chain, aiming to explore how supply uncertainty impacts SCP and to propose management interventions accounting for uncertainty. The majority of the uncertainties identified were related to suppliers and external sources, caused by factors such as late delivery of catch, fishers selling to other buyers, regulations and weather. By integrating suppliers in planning and supplier development programs uncertainty can be mitigated. External and inherent related uncertainty such as changes in catch quotas and weather conditions must be manged by monitoring, forecasting, and preparedness.

Keywords: supply uncertainty, white fish raw material, supply chain planning, tactical planning.

Introduction

Recent studies have highlighted the negative impact of supply uncertainty on supply chain performance, such as inefficient capacity utilization, risk and cost of over- and understocking, unreliable availability of materials and poor service level (Nyamah et al., 2017). If manufacturers do not receive the right volume of raw material at the right quality, time and place, production will be delayed, order fulfilment prevented, costs will occur and competitiveness decline (Chaudhuri et al., 2014).

Supply chain planning (SCP) aims to mitigate uncertainty through coordinating and integrating key business processes from raw materials procurement, production, distribution and sales, and by managing demand and supply (Jonsson and Holmström,

2016). SCP is particularly important in planning environments with long-term uncertainty (Gupta and Maranas, 2003), where decision-makers struggle to predict internal and external long-term changes, in contrast to short-term day-to-day variability from processing variations, rushed orders/cancellations and equipment failure, where event management is more important. Tactical mid-term planning absorbs uncertainty by the time horizon adopted, the level of aggregation (product group/family and production network), cross-functional structure and alignment of strategic and operational decisions.

Most of the SCP literature focuses on uncertainty from a tactical production planning view (Guan and Philpott, 2011), or addresses sources, causes, disruptions and consequences of uncertainty (Simangunsong et al., 2011). To date a few studies analysis supply uncertainties in the food supply chain (Chaudhuri et al., 2014), but there is no comprehensive review concerning the role and impact of supply uncertainty on the SCP process (Ivert et al., 2015), and how managing the planning process can adapt in the event of supply uncertainty. This study aims *to explore the feature of supply uncertainty; how supply uncertainty impacts SCP and to propose management interventions accounting for uncertainty*.

In contrast to industries where raw material supply is reliable, unproblematic and products are durable and easily stored, the present study analyses the whitefish industry, which handles raw materials that are characterised by fluctuations in availability caused by uncertainties including weather conditions, seasonality, quality variations and products with limited shelf life (Romsdal, 2014).

The remainder of this paper is organised as follows: First, based on literature we describe the theoretical background for analysing the SCP process and the supply uncertainty. Second, the research design is described. Third, we analyse the SCP processes in one case from the whitefish processing industry; the results are used to identify management strategies for mitigating supply uncertainty. We discuss our findings in relation to previous literature and propose recommendations for producers and for future research.

Theoretical background

SCP aims to improve performance in operations, and to stabilize and better align operations with business strategy and partners in the supply chain (Gupta and Maranas, 2003). It is a management intervention mechanism for coordinating and integrating supply and demand activities through organizational collaboration (Jonsson and Holmström, 2016) in order to create supply chain value (Oliva, 2011). The basic mechanism in planning is to decide on what and how much should be produced, when, how and what resources are needed for achieving the intended outcomes (Jacobs et al., 2011). Uncertainty increases the planning complexity, making managerial interventions such as planning on rolling horizons and flexible production mix, important from a supply chain perspective (Bakhrankova et al., 2014; Chaudhuri et al., 2014; Graves, 2011; Bozarth et al., 2009).

The literature background is structured around the elements of SCP as managerial interventions, in particular the *processes* applied to manage operations and relationships (Jonsson and Holmström, 2016) and the impact of *supply uncertainty*.

SCP process parameters

Planning can be seen as a process consisting of sequences of decisions and the interdependency of planning *activities* across time and space (*setup*) (Jonsson and Mattson, 2009), with a beginning and an end, and with clearly identified *inputs* and *outputs* (Oliva and Watson, 2011). Planning has several levels, but in SCP the tactical

aspects concern the coordination of demand and supply on a medium- to long-term time-horizon (Fleischmann et al., 2015), involving inbound, operations and outbound stages in the supply chain (Stadtler, 2005). In cases of highly variable supply, such as in the food and retail industry, it may be beneficial to involve suppliers in the planning process (Yurt et al., 2010; Dreyer et al., 2018).

A recognized framework for SCP is S&OP which is a medium-term, cross-functional process aimed at coordinating demand and supply planning (Ivert et al., 2015). Since S&OP includes the whole process from supplier to customer, and it has been applied in food manufacturing studies the analysis in this study is adopted from the S&OP framework presented by Thomé et al. (2012), categorizing the planning process into a number of *setup* and *process* parameters.

The set-up parameters include planning *frequency*, planning *horizon* and planning *object* (Ivert et al., 2015). S&OP is a monthly process (Jacobs et al., 2011) that undertakes aggregate planning at a time horizon of 6-24 months, depending on the complexity of the products (Fleischmann et al., 2015; Peidro et al., 2009; Gupta and Maranas, 2003).

Planning parameters are *input*, *activities* and *outcomes*. Input parameters can according to Ivert et al. (2015) be divided into three groups: separated plans (e.g. demand, sales, production, procurement and capacity plans), constraints (production capacity, supplier constraints and financial restrictions) and goals. Activity parameters are the structure and process element that encompass: meetings and collaboration; organization; information technology; and S&OP metrics (Thomé et al., 2012). The outcome parameter is plan integration (Thomé et al., 2012). In the food industry, Ivert et al. (2015) found in their case study that the outcome mostly was integration of production plans. However, results from the literature review in Thomé et al. (2012) include plans from various functions within the company.

Supply uncertainty

Van der Vorst and Beulens (2002) consider supply chain uncertainty to be decision making situations where the decision-maker is unsure about the best course of action. This can be due to unclear objectives, lack of information, inaccurate predictions on the impact of possible control actions on supply chain behaviour, or the absence of effective control actions. Further, supply uncertainty comes in four forms; variations in quantity, quality, price or supplier lead time (Chaudhuri et al., 2014), and is considered as one of the sources of uncertainty in the uncertainty circle model (Mason-Jones and Towill, 1998).

Supply uncertainty can be decomposed into four sources: *inherent characteristics*, *supply chain* related, *external* and *supplier* related (van der Vorst and Beulens, 2002). Inherent characteristics are built in the nature of the product or raw material, such as perishability. Supply chain related uncertainty are features of the supply chain that cause disturbances in system performance (van der Vorst and Beulens, 2002). External uncertainty includes changes in products, markets, competitors and regulations set by the government. Supplier related uncertainty regards capacity and quality variations that are caused by the suppliers' processes and organization (Chaudhuri et al., 2014). The literature study has been structured in the framework in Table 1.

Table 1 – Sources and drivers of uncertainty with their respective references (adapted from van der Vorst and Beulens, 2002 and Chaudhuri et al., 2014)

Sources of supply uncertainty	**Drivers of supply uncertainty**	**Author(s)**
Inherent characteristics	Inverted bill-of-materials	*Chaudhuri et al. (2014)*
	Lack of homogeneity	*Chaudhuri et al. (2014), Esteso et al. (2017)*
	Perishability	*Chaudhuri et al. (2014), Esteso et al. (2017), Srivastava et al. (2015), Behzadi et al. (2017), Bakhrankova et al. (2014), Rijpkema et al. (2016)*
	Pests and diseases	*Esteso et al. (2017), Zhao et al. (2017), Behzadi et al. (2017)*
	Weather	*Esteso et al. (2017), van der Vorst and Beulens (2002), Chaudhuri et al. (2014), Zhao et. al (2017), Behzadi et al. (2017), Borodin et al (2016), Nyamah et al. (2017)*
	Antibiotic resistance	*Zhao et al. (2017)*
	Seasonality	*Chaudhuri et al. (2014), Behzadi et al. (2017), Srivastava et al. (2015)*
Supply chain related uncertainties	Location of suppliers	*Chaudhuri et al. (2014)*
	Number of suppliers	*Srivastava et al. (2015), Chaudhuri et al. (2014)*
	Lack of internal integration	*Van der Vorst and Beulens (2002), Chaudhuri et al. (2014)*
	Lack of visibility and information sharing	*Dreyer and Grønhaug (2012), Bakhranova et al. (2014), Srivastava et al. (2015), Rijpkema et al. (2016), Chaudhuri et al. (2014)*
	Poor contracts	*Borodin et al. (2016), Srivastava et al. (2015)*
	Lack of traceability	*Srivastava et al. (2015)*
Supplier related uncertainties	Maintenance of equipment	*Chaudhuri et al. (2014)*
	Not investing in new equipment	*Chaudhuri et al. (2014)*
	Lack of training	*Chaudhuri et al. (2014)*
	Poor material handling at supplier	*Nyamah et al. (2017)*
External uncertainties	Governmental regulations	*Chaudhuri et al. (2014)*
	Natural disasters	*Zhao et al. (2017), Christopher (2016)*
	Terror, war, etc.	*Srivastava et al. (2015), Christopher (2016)*
	Political issues	*Zhao et al. (2017)*

Research design and method

A literature study was conducted, drawing on the current body of knowledge in supply chain planning and supply uncertainty. Based on the methodology by Denyer and Tranfield (2009), 1112 papers were considered, 131 abstracts were assessed, and 23 papers were selected for full-text review. An analytical framework for the SCP process and supply uncertainty was developed from literature and guided the case study in the Norwegian whitefish industry. Considering that the study aimed to investigate features of supply chain uncertainty and the impact on SCP, the case study methodology was the preferred research strategy (Yin, 2009). The method gave access to in-depth data about the context and the supply chain planning process, as well detailed information about the supply uncertainty and impact for SCP.

The unit of analysis was the tactical supply, production and sales planning process of a white fish processor. The company produces and sells a wide range of wild catch whitefish products – fresh and frozen, mainly from three fish species. Fresh products are the main category and the one in focus in the present study. Customers are domestic and international retailers and food services companies. Products are being produced in 7 plants located along the Norwegian coast. The case was selected based on the characteristics of the company and the industry; the market is highly regulated, exposed to variability in raw material access and seasonality, raw material price auctions, quality and perishability of raw material (Nilssen et al., 2014). In addition, recent studies agree that poor profitability among white fish producers can be traced back to the uncertainty in supply (Chaudhuri et al., 2014), indicating that planning and maximising the output from raw material and production capacity is challenging, with implications for the whole supply chain.

The data sources appear in Table 2, mostly consisting of semi-structured interviews and workshops. The workshops were guided by thematic agendas and interviews were guided by a case study protocol. Each session was recorded and transcribed to ensure that all the information from the interviews was captured. Data were coded and analysed according to the analytical frameworks.

Table 2 – Data collection

Data source	Data object	#
Semi-structured interviews	Central planner	5
	Processed white fish manager	3
	Business analyst	1
Reports	Pre-study report	1
	Previous master's theses from the same research project	2
Site visits/workshops	Case company	3

Case analysis

This section presents the case analysis, starting with supply uncertainty, SCP process and ends with a summary.

Supply uncertainty

The supply uncertainty identified by the company is categorised according to the framework in Table 1 and weighted to identify the severity of the uncertainties (Table 3). The uncertainties were assessed on a scale from 1-5 (with intermediate evaluations) by likelihood and potential impact (with respect to planning), and the severity was established by multiplying the respective values.

Table 3 – Supply uncertainty evaluation

Source of uncertainty	Uncertainty	Probability	Impact	Severity
Supply chain related uncertainties	Under/over estimation of raw material	5	4	20
	Lack of information from suppliers	2	4	8
External uncertainties	Changes in catch quotas	4	4	16
	Weather conditions	4	3.5	14
	Expensive raw material	3	4	12
Supplier related uncertainties	Fishermen selling to other buyers	4	4	16
	Late delivery of catch (time)	4.5	3	13.5
	Suppliers fail to deliver contracted volume	2	4	8
	Raw material quality is not conserved by fishermen	2.5	3	7.5
Inherent characteristics	Fish migration	4	3	12
	Poor raw material quality	3	3	9

Table 3 shows that the majority of the uncertainties were related to *supplier* (4 of 11) and *external sources* (3 of 11 uncertainties). Two of the supplier-related uncertainties (fishermen selling to other buyers and late delivery time of catch) are considered having high severity (16), while suppliers failing to deliver according to contract and maintaining quality were rated lower (8). All external uncertainties received relatively high severity scores (between 12 and 16). For *supply chain* related uncertainties (2 of 11), forecast accuracy is considered as critical and receives the highest score of all 11 factors (20). For the *inherent characteristics* (2 of 11), fish migration got a relatively high severity score (12). The most frequent planning dimension affected by the identified uncertainties is raw material quantity, followed by quality, price and lead-time.

Supply chain planning process

The first stage in the SCP process is to create the raw material plan, identifying the availability of the raw material and raw material mix. Based on this plan, a production plan including product mixes for each facility in the network is created. Further, sales and procurement plans are created and coordinated with the production plan as shown in Figure 1. The tactical plans are aggregated and the time horizon adopted is one year, continuously updated once a week with new information, such as when the quotas are adjusted. Through weekly meetings the plans are disaggregated and adjusted with the overall objective of optimizing the sales, production and procurement.

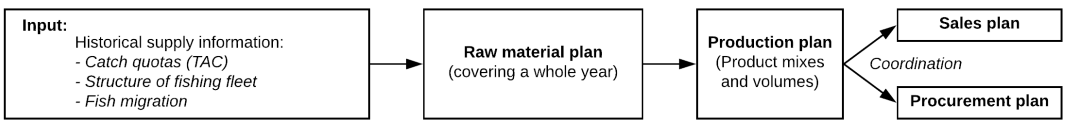

Figure 1 – The tactical planning process at the case company

Concluding the case analysis, the main uncertainties are related to *suppliers* and the *supply chain* (highest severity score), as well as uncertainty concerning the access to raw material quantity. Some of the uncertainty factors are difficult to manage such as weather conditions and changes in catch quotas, while others such as fishermen selling to other

buyers and lack of information from suppliers are uncertainties that can be managed. The tactical planning is strongly affected by the supply uncertainty which make the raw material plan essential for SCP. Tactical planning is based on the long-term raw material plan and is coordinated between procurement, production and sales to mitigate uncertainty. When entering the peak-season, plans are disaggregated and coordinated towards sales and marketing, increasing frequency of meetings and plan revisions.

Discussion

The role of tactical planning is to coordinate long-term and aggregated operations decisions with business strategy and partners in the supply chain (Jonsson and Holmström, 2016). The planning is based on experiences and history, creating expectations and predictions about the future state, and by such absorbing uncertainty and improving SC performance (Gupta and Maranas, 2003). The present study understands planning as managerial intervention, aiming to mitigate uncertainty by preparing operations for future events.

Wild fish is a raw material particularly exposed to uncertainty as showed in the presented analysis, supporting Ivert et al. (2015). The core tactical planning activity is the planning of raw material, whereas procurement, production and sales/market plans heavily depend on the raw material availability while also considering quality, lead time and price. To manage the sourcing of raw material was a competitive advantage, identified also by Bakhrankova et al. (2014), and the key to achieve high added value from the raw material, utilization of production capacity and to release the market potential and sales. Since several of the supply related uncertainty factors were considered as substantial and long-termed, raw material information (volume, quality class, size, species, shelf life, catch location, time of the catch, time before delivery, etc.) is carefully reviewed by the planners in the initial planning phase.

The raw material plan is a critical input to the production planning, particularly the production network planning and the allocation of raw material between the production plants to maximize capacity utilization. The plants differ in terms of capacity, technology and delivery lead-time which depend on where the catch was caught and landed. Since the production planning aims to secure a high utilization of the raw materials and the production network capacity, managing supply uncertainty is critical.

For sales, the raw material status is decisive for maximising the outcome of the products, particularly for fresh products. Precise information on the product mix and volume are the main elements in the selling activity/customer/contract negotiation. If sales are provided with an accurate raw material forecast it will strengthen the sales negotiation position, both in terms of own production/delivery capability and on competitors' sales abilities. If the forecast is inaccurate and production volume turns out to be higher than expected, a higher volume must be sold which could negatively impact the price level. Opposite, if the sellers know that due to lack of raw material, sales volume will be lower than the marked demand, then the price could be increased, which is particularly important for the fresh product assortment. Further, failing to forecast the changes in quotas can lead to engagement in contracts missing out on great profits.

Strategic supplier contracts are applied to dampen some of the supply uncertainty, which correspond with the findings by Srivastava et al. (2015). However, in the high peak season during the winter, fisheries mostly source raw material from the coastal fishing fleet where it is the price and landing service/facilities settling the sales and not long term contracts – causing uncertainty.

A planning horizon of several months is applied to dampen the implications caused by high seasonal variability in fisheries; changes in volumes, mix of species, and the long

delivery lead-times in the off-season. Additionally, the tough national regulations of raw material, the raw material market and price mechanism made the long planning horizon necessary.

The planning structure applied is aiming for balancing sales and market driven planning with production capacity/network driven planning. By focusing on the market and sales potential, offering value adding products to customers willing to pay extra for quality is expected to be more profitable than mere selling what can be produced. To avoid uncertainty accumulation for the individual plants, the tactical planning is centralized and coordinated between operations and sales/market. However, the centralisation may cause tension between the plants since they are measured individually (profit, amount of raw material purchased relative to the total catch in the local region). To avoid conflicts of interests' weekly team meetings (Skype) are applied to create transparency and consensus about the allocation decisions.

Conclusion and proposal for mitigating supply uncertainty in SCP

This paper analyses the whitefish processor regarding SCP uncertainty mitigation strategies. The uncertainty sources were categorised as supply chain uncertainties, supplier uncertainties, external uncertainties and inherent uncertainties, while the SCP process is composed of planning set up parameters (frequency, horizon and objective) and process parameters (input, activities and outcome). These frameworks helped in analysing the characteristics of a whitefish processor case and to identify aspects of uncertainty in SCP which can help in mitigating uncertainty.

The uncertainty factors in the case can divided in two categories; the manageable factors which can be mitigated by the planning process and the factors that are unmanageable. The *supplier* and *supply chain* related uncertainties are caused by factors such as forecast errors, lack of information and late deliveries which can be addressed and managed to mitigate uncertainty. Interventions can be to integrate suppliers in planning, maintaining a portfolio of suppliers and supplier development programmes leading to collaboration, commitment and contract terms with collaborative incentives, price mechanisms and risk sharing. Mitigating uncertainty by integrated tactical planning is particularly important when uncertainty is long-termed such as seasonality and quota systems. Unlike managerial factors, *external* and *inherent* related uncertainties require a coping planning approach, were the focus should be on gaining high quality information and data about the uncertainty sources by monitoring, systemising and analysing information applied in long term planning. Integrated tactical planning

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