One size does not even fit one: supply chain strategies in the decline phase

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Abstract: Given that aligning supply chain strategies with changing product characteristics across the phases of the product life cycle is increasingly important, this study investigates the changes in supply and demand uncertainty when a product enters the decline phase and how these changes in turn affect the supply chain strategies applied. Based on four case studies, the analysis reveals that the uncertainties increase in three of four cases when the product enters the decline phase, and that the type of uncertainty, as well as the related challenges, depends on the product's initial uncertainty of supply and demand. This implies that companies need to redesign their supply chain strategies towards either more lean or more agile supply chains, or combinations thereof, when the products are declining.

Keywords: supply chain strategy; product life cycle; PLC; decline phase; lean; agile; demand uncertainty; supply uncertainty; product characteristics.

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1 Introduction

The rapid development of new technologies and highly competitive markets increasingly compresses product life cycles (PLCs). A shorter PLC creates increased pressure to quickly adjust a product's supply chain strategy in order to respond to changing demand and supply uncertainties. For example, when a product is in its introduction phase, little is known of actual customer demand, and supplier capacities have typically not been secured. When the product eventually matures, demand and the supply process stabilise. Not a new observation, this process was described 40 years ago by Hofer (1975). But precious little literature has analysed what actually happens in the decline phase, some of which needs an update. For example, Anderson and Zeithaml (1984) found that uncertainty is usually low in the decline phase, but recent models suggest that volatility increases, owing to both diminishing volumes and the shift when a product moves from the mature to the decline phase (Hsueh, 2011; Nepal et al., 2012).

The relevance of the issue was already pointed out by Lee and Sasser (1995), who argued that the decline phase should be considered beforehand when developing a supply chain strategy for a new product, in order to reduce the cost of excess inventory,

obsolescence and excess purchased material. However, Lee and Sasser (1995) do not further analyse which supply chain strategies are appropriate. The lack of literature on the topic is surprising, considering that already in 1998, Birou et al. indicated that purchasing, production and logistics managers ignored the decline phase, and they pointed to the need for special attention to this area.

Although there have been some discussions of the impact of PLC on supply chain strategy (e.g., Aitken et al., 2003; Doha et al., 2013; Mahapatra et al., 2012), discussions of the decline phase have been superficial at best. In particular, no present study thoroughly analyses how the shift in the PLC cycle affects supply and demand uncertainty, which have been identified as key drivers of supply chain strategy by Lee (2002). The purpose of this paper is to investigate the changes in supply and demand uncertainty when a product enters the decline phase and to analyse how the changes and related challenges differ depending on the company's initial uncertainty of supply and demand. A second purpose is to explore the implications of the changing product uncertainties for the supply chain strategies applied.

An obvious effect of products entering the decline phase is that their volume declines. An equally obvious reaction to declining volumes is to cut back and adapt capacity. This paper does not primarily discuss these issues, instead focusing only on changes in uncertainty of supply and demand. Moreover, we concentrate on the decline phase, not on the product's end-of-life (EOL). Furthermore, since other authors have researched how to manage mature and declining industries (e.g., Sousa and Hambrick, 1998), that issue is also beyond the scope of this paper. Instead, the study contributes to both supply chain management (SCM) and PLC literature by explicitly focusing on supply chain challenges, uncertainties and strategies in a product's decline phase. We reveal the challenges for managing supply chains when products have entered the decline phase and propose ways to redesign supply chains given the associated changing supply and demand uncertainties.

The paper is based on an explorative case study of four products from various industries. The products were selected based on contrasting supply and demand uncertainties. After reviewing the PLC and SCM literature and the connection between the two, we describe and analyse the four cases. Finally, we conclude by stating four propositions concerning the effects of the PLC on the supply chain.

2 Literature review and theoretical framework

In this section, general literature on the PLC and literature specific to the PLC in the supply chain will be reviewed. Key concepts will be explained and connected to each other in a theoretical framework.

2.1 The PLC

The PLC is widely discussed as a key to strategic marketing planning. Already in the 1960s, Cox (1967) showed that all products go through a series of phases, which he called the PLC. Typically, a PLC is classified into four distinct phases (Cox, 1967): introduction, growth, maturity and decline. Marketing strategy has to change dynamically to match each phase of the PLC. For instance, when a product is in its decline phase, as

sales show a downward drift and profits erode, the company must adopt strategies to withdraw it from the market. Nonetheless, "most companies have not developed a policy for handling aging products" [Kotler and Keller, (2013), p.315]. It is often very costly to continue selling an ageing product instead of a new one, as it leads to overcapacity, increased price cutting and profit erosion. Kotler and Keller (2013) suggest that an appropriate marketing strategy for a declining product depends on the industry's relative attractiveness and the company's competitive strength in it. Hofer (1975) and Anderson and Zeithaml (1984) brought the PLC concept into the business strategy literature. Hofer (1975) identified the PLC as the most important variable when deciding on overall business strategy and highlighted the imperative of changing strategy when the products shift from one phase to another. Anderson and Zeithaml (1984) conclude that changes in strategy are both common and advisable along the PLC. An appropriate strategy in the decline phase, they argue, is to focus on efficiency while reducing investments. The number of articles discussing the PLC has declined sharply in recent years, partly due to the difficulty of applying the concept (Cao and Folan, 2012). For example, even though it remains widely accepted that products experience PLCs, it remains difficult to forecast when the product will switch from one phase to the next (Cao and Folan, 2012).

2.2 The PLC in the supply chain

Compared with the attention to PLC in the marketing literature (e.g., Cox, 1967; Kotler and Keller, 2013), an SCM perspective on PLC is rare, even though Anderson and Zeithaml (1984) found that process efficiency becomes more important when products mature. Karlsson and Nyström (2013) similarly observed that innovation and knowledge differ between the different stages of PLC, one reason being that product innovation shifts to process innovation when products mature (see also Utterback, 1996), implying a shift towards SCM issues.

Pagh and Cooper (1998) argue that supply chain strategies should change as a product proceeds through its life cycle, but give little guidance on the content of the strategy. Juttner et al. (2006) conclude that supply chain alignment competence is closely linked with PLC management; they suggest a general conceptual model for supply chain strategy and PLC management. However, their study does not offer supply solutions for the life cycle's different phases. Likewise, Mendelson and Pillai (1999) discuss the impact of the PLC on supply chain measurement and operations implications in general, but do not analyse how these differ in the different PLC phases. Towill (2001) illustrates cost control of various types of automotive components in different phases of their life cycles. Aitken et al. (2003), one of the few studies that do show that the PLC has an impact on supply chain strategy, considers only the internal SC and offers only materials supply strategies such as material requirements planning (MRP) or kanban. For the decline phase, Aitken et al. (2003) recommend using MRP systems in order to handle a large number of low-volume products. In contrast, the large volumes of the mature phase are best served by a lean SC using kanban.

Nepal et al. (2012) showed in a model that the bullwhip effect is also adversely affected by the PLC, so that when the product shifts from one phase to another, the volatility of demand tends to increase, and the volatility gets amplified when moving up the SC. In Hsueh's (2011) model, inventory and production vary depending on the phase of the PLC. Hsueh (2011) concludes that different inventory control policies should be

adopted in different phases; in the decline phase, batch sizes should be reduced and inventory continuously reduced.

Cebon et al. (2008) and Sanchez (2008) have explored production risks in the decline phase. They observed that when products mature, they become increasingly standardised and volumes grow, while companies' production structure becomes more rigid in order to maximise process efficiency. As soon as the products come into decline and the volume is reduced, the process structure is no longer optimal, but the ability to change has become reduced.

A few other studies integrate the PLC with purchasing strategies. Birou et al. (1997) showed that the sourcing strategies vary in different phases of the PLC. Doha et al. (2013) mentioned that purchasing practices and their efficacy are indeed contingent on the PLC. For example, the selection of supplier is more often based on innovation and likely to result in higher quality in the growth phase compared to the mature phase. However, Doha et al. (2013) do not analyse purchasing in the decline phase. Wang (2004) suggests that the supplier relationship varies from 'single source' to 'dual source' and then to 'open source', following the product's life cycle stages. Narasimhan et al. (2006) find that although firms are often trying to exploit economies of scale and buy multiple products from the same suppliers, they face difficulties in assigning appropriate supplier selection criteria when each product is at a different phase of the PLC.

2.3 Theoretical framework

Since the impact of the PLC on the supply chain can be attributed to how it affects supply and demand uncertainty, SCM literature that links the uncertainty to supply chain strategy can provide guidance on how to handle the supply chain in the PLC. The many risks and uncertainties supply chains face have been thoroughly reviewed by authors such as Manuj and Mentzer (2008) and Peidro et al. (2009). Broadly, they consist of three types: supply, demand and process (Peidro et al., 2009), but very few studies have considered all three. In this paper, we will confine ourselves to one of the most commonly used uncertainty models.

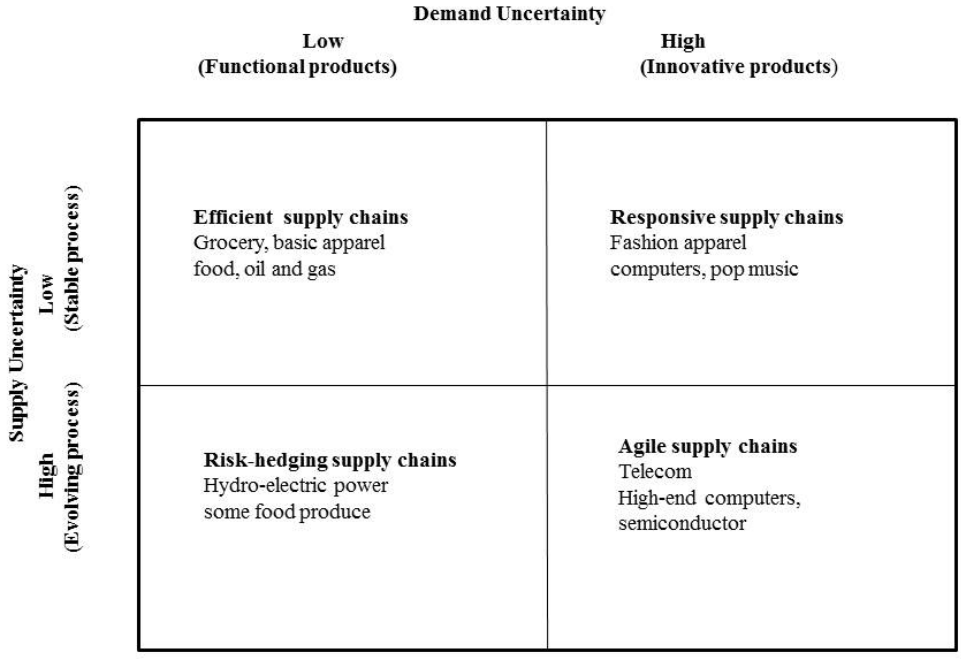
Fisher (1997) introduced a framework for selecting 'the right supply chain for the right product' based primarily on demand predictability. A functional product, which is defined as having stable, predictable market demand and a long life cycle with low profit margins, requires an efficient SC, whereas an innovative product, identified as one with unpredictable demand and short life cycle but often high profit margins, requires a responsive SC. Fisher's model has been found largely valid (Selldin and Olhager, 2007), although a few studies have found that the model is far too simplistic and more detailed factors are needed (Lo and Power, 2010). Von Haartman (2012) found that Fisher's model still has some merits, but that technological maturity is a key driver of supply chain strategy. Other studies have found that supply uncertainty, not demand uncertainty, is a key driver of sourcing strategies (Paulraj and Chen, 2007).

As a development of Fisher's (1997) model, Lee (2002) argues that there are two key uncertainties faced by the product: demand and supply. Thus, Lee (2002) expands this 'uncertainty framework' to include supply uncertainty, which is defined as manufacturing processes with underlying technology as well as uncertainty in the established supply base. Lee's (2002) supply dimension is thus a combination of the supply and process dimensions that Peidro et al. (2009) defined and reviewed. Demand uncertainty can be

broadly defined as uncertainty in forecasting market demand and product variability. Innovative and functional products are different in terms of sales forecast, product variety, cost of stockout and obsolescence, etc., and require different types of supply chains (Figure 1).

Both Fisher's (1997) and Lee's (2002) models prescribe different supply chains for different products, based on different demand and supply uncertainties. Neither Fisher (1997) nor Lee (2002), however, analyse how to alter the supply chain strategy to match a product's changing uncertainties during its life cycle.

Figure 1 Matched supply chain strategies in a product uncertainty framework



Source: Adapted from Christopher et al. (2006), Lee (2002), Towill and Christopher (2007)

In addition to Fisher's conceptualisation, 'lean' and 'agile' supply chain strategies are considered two distinct models of business operations (Towill and Christopher, 2002). The purpose of lean supply is to remove non-value-added activities, or waste, and make the SC as lean as possible (Drake et al., 2013). Whereas the concept started with lean manufacturing in the 1990s (Womack et al., 1990), it is only recently that lean has been applied to the supply chain and logistics management area (Myerson, 2012). In contrast to lean, agile supply aims to respond to any change in demand as quickly as possible (Christopher, 2000). An agile supply chain is appropriate when demand is uncertain, products new and innovative, and customer expectations are unknown or change fast (Routroy and Shankar, 2015). The agile concept is often used in flexible manufacturing systems to quickly respond to unpredictable market demand.

Lean supply chain strategies focus on eliminating waste and improving efficiency to provide products at lower cost, when both supply and market demand are reasonably stable. In contrast, agile supply chain strategy focuses on a quick response and high

service level to meet unpredictable market demand, sometimes amid high supply uncertainty (Naylor et al., 1999). Thus, the choices of lean and agile supply depend on different product characteristics, i.e., supply and demand market uncertainties. As a combination of lean and agile approaches, 'leagile' supply is considered a third option of supply chain strategy for when market demand is volatile but supply uncertainty is low (Christopher et al., 2006; Naylor et al., 1999). The concept 'agilean' is another integration of the agile and lean concepts. It is characterised by uncertain supply but relatively stable market demand (Towill and Christopher, 2007). The agilean supply chain is not common but does occur in a few industries, such as food production. Drake et al. (2013) conclude that a lean supply chain strategy is best for quality and cost, agile is best for time-based competition and flexibility, and a leagile supply chain strategy is needed when all four factors are important.

Although a pure lean or agile strategy may be the most suitable for a product's supply chain, real industrial life is often more complicated (Lo and Power, 2010; von Haartman, 2012). One company often possesses different product groups and families with demand and supply characteristics that vary greatly. A company cannot choose only one supply strategy for different products, but usually a combination of two supply chain strategies. Thus, Christopher (2000) recommends a hybrid supply chain strategy. This hybrid option is often appropriate when a company's product portfolios and markets are diverse (Christopher, 2000; von Haartman, 2012). However, no authors discuss how a hybrid supply chain concept like leagile is linked with one product's change in PLC phase.

In summary, surprisingly little research has been done on connecting the PLC to SCM, and no recent empirical study has analysed the SC implication of products entering the decline phase. So far, the discussion of supply chain strategies is based on either different product characteristics (Fisher, 1997; Lee, 2002) or different companies (Towill and Christopher, 2007). The literature still lacks a discussion of supply chain strategies along one product's life cycle, particularly when the product is in the decline phase. Hence, two research questions can be formulated:

1 How does supply and demand uncertainty change when products are entering the decline phase?

2 What implications do the changes in supply and demand uncertainties have for the supply chain strategies?

3 Method

Since this paper aims to explore SCM challenges and how product uncertainties may affect supply chain strategies in the decline phase, an explorative case study is most suitable. To discuss the two research questions, the key issue is to explore how the demand and supply characteristics change when the products switch from the mature to the decline phase. The unit of analysis is the transition of the product in its decline phase in terms of the demand and supply uncertainty. Four case studies were selected based on their positioning in relation to each other in terms of supply-demand uncertainties. In selecting the cases we were inspired by Lee (2002) and Towill and Christopher (2007), who uses predictability of market demand and product variability as demand uncertainty

aspects; we also chose supply source uncertainty and lead time as supply uncertainty aspects.

The selected products were a radio base station, an infrared camera, a stapler and a taco sauce. In relation to each other, the radio base station has high demand and supply uncertainty; the infrared camera has high demand uncertainty but low supply uncertainty; the stapler has low demand and supply uncertainty and the taco sauce has high supply uncertainty but low demand uncertainty (Table 1). All of the selected products can be defined as mature products.

The period of data collection was between August 2012 and December 2013 and the study was made in two steps. First, a pilot study of the telecom company and the radio base station was made. The pilot study focused on identifying key concepts and refinement of the method in terms of, e.g., selection of key informants. It started with a workshop and was followed by a larger number of interviews. Thereafter, the forthcoming three comparative case studies (2–4) were made. In sum, researchers conducted intensive semi-structured interviews with 24 people involved in product management, SCM and sales (see Table 1).

Table 1 Interviews conducted at each firm during 2012–2013

Selected firms in case studies	*Selected product and its relative characteristics*	*Job title of the interviewees in the firm*
Case 1: A highly technologically driven firm in telecom industry	Radio base station 3G (RBS3G) with high demand uncertainty and high supply uncertainty	Director of operation efficiency in SCM
		Head of supply chain control
		Sourcing managers for RBS3G and 4G (3)
		Production manager for RBS3G
		Logistics manager
		Cost control manager
		Director of production of RBS3G
		Project manager of RBS3G
		Director of phase-out management
		RBS3G phase-out project manager
		Global service manager
Case 2: A very technologically driven firm in the thermal imaging (infrared) camera manufacturing area	Infrared camera with high demand uncertainty and low supply uncertainty	Sourcing manager
		Supply chain manager
		Production manager
		Product manager
Case 3: A paper fastener manufacturing firm in the office tools industry	Stapler A100 with low demand uncertainty and low supply uncertainty	Logistics manager
		Production manager
		Product manager
Case 4: A firm that produces and trades goods for flavouring, such as spice mixes and sauces in the food manufacturing industry	Taco sauce with high demand uncertainty and low supply uncertainty	Purchasing manager
		Production manager
		Product manager
		Marketing and sales manager
Sum		24 interviews

During the interviews, an extended research team consisting of the authors and a few more researchers asked general questions on the PLC and supply chain strategies, as well as competitive priorities and challenges the interviewees have experienced. In addition, the interviews contained in-depth questions about the decline phase in terms of identification of the phase, information management, responsibilities, and organisational linkages and structures. Each interview was conducted with at least two researchers present in order to use the complementary experience and perspectives of the researchers during and after the interviews. Company documents describing market and supply chains were also studied to triangulate data.

Using the interview notes, the interview themes were used for structuring the data and event lists; graphic illustrations were used for pattern recognition (Miles and Huberman, 1994), structured along the two main dimensions of supply and demand uncertainty. In addition, additional workshops were organised, focusing on experiences and lessons about how supply chain design links to the PLC, especially in the decline phase. In order to enhance the validity of the paper, the interviewees validated the case study findings and analyses.

The data was analysed by the use of a framework based on Lee (2002), Christopher et al. (2006) and Towill and Christopher (2007) (see Figure 1). Drawing from the framework, we analysed different aspects of the demand and supply uncertainty dimensions. Each aspect was, in turn, classified as having increased, lessened or stayed roughly the same after the transition from the mature to the decline phase (see Table 2). The result of the analysis was then graphically illustrated in a supply and demand uncertainty matrix (see Figure 4), showing the relative transition of the respective product when moving into the decline phase.

One strength of this study is the joint analysis over a longer period of time within our research group. The group has a mix of academic, industrial and consulting experience. One of the authors has been a consultant in telecom or other industrial sectors for many years and has had the opportunity to discuss supply chain strategies with different companies. Another author has been working in the telecom sector for more than 40 years, providing deep knowledge of products and markets, as well as supply chain strategies and practices. The other three authors each have more than ten years' research experience in SCM and/or industrial management within selected industrial sectors and have thus been able to build up the research team's joint knowledge base. The mixed competencies thus strengthened both our data access and our analysis ability.

Our chosen methodological approach has limits. Since the case studies are explorative in character, generalisability is limited. However, our purpose is not to test or suggest general strategies on how to manage supply chains in the decline phase, but rather to explore and illustrate what the challenges might look like and how they can be managed (Voss et al., 2002).

4 Case studies

The purpose of the case study is to observe the changes in products' demand and supply uncertainty when selected products are switching from the mature to the decline phase, as well as the challenges for SCM.

4.1 Case 1: radio base station 3G product with both high demand and supply uncertainty

4.1.1 The RBS3G PLC and its SC

This case company, which provides large telecom systems and service around the world, is facing the challenge of shortened PLCs for its products. Radio base station 3G (RBS3G) came into the market in the early 2000s, but the ramp-up of RBS4G was quicker than for earlier generations and the company started the decline of the older RBS3G product in 2012. As a typical high innovation product, the RBS3G is a product with high uncertainty on both the demand and supply sides, which corresponds to the need for an agile supply chain.

4.1.2 The SC changes when the RBS3G moves to decline

To review the RBS3G's supply chain changing along its PLC, we organised a special workshop together with the company's SCM department. One example shows how the product's production changed during its life cycle. When the RBS3G was in its introduction phase, the first manufacturing activity started in the company's master factory in early 2000. As soon as the RBS3G product came into the growth phase, the company expanded production to several manufacturing suppliers in the European market. When the RBS3G became mature, with growing market demand globally, production switched to a regional strategy, i.e., several factories were setup in five regions worldwide, utilising both its in-house and outsourced resources. However, when the sales volume started to decline after 2010 due to market competition, the company consolidated the RBS3G production from five regions to one, close to both the product's main suppliers and its biggest markets.

4.1.3 Uncertainty challenges for SCM

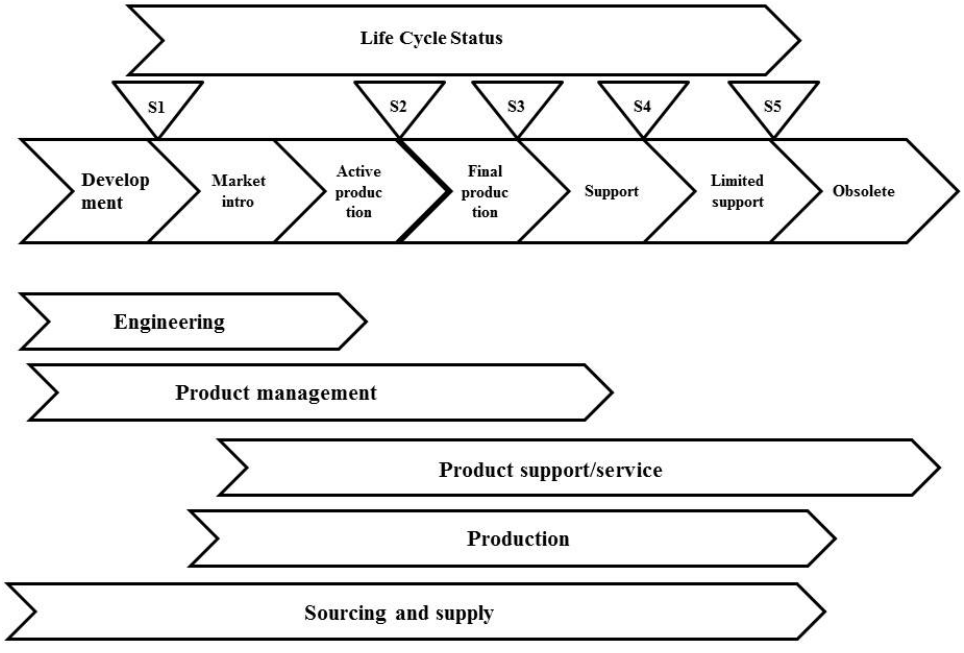
When the RBS3G declines, its product uncertainties increase in both demand and supply processes. From the demand side, customers who prefer the current RBS3G may increase order volume for their own buffer when the RBS3G announces 'last time buy', whereas other potential customers might stop buying the RBS3G in favour of the new RBS4G. Another risk involves new orders from emerging markets after the company has decided to reduce volumes. Meanwhile, the supply uncertainty increases due to consolidation, the limited supply source and resulted longer product lead time and so on. On the other hand, the company's decline decision means the last time a new order will be accepted is in six months, and the end of all supply activities will be in 12 months. Since some components' lead times are longer than six months, there is a risk of inventory cost of over-purchased components when the product finally reaches EOL. The company also experienced overproduction towards the end of product life, which resulted in an obsolete inventory of finished goods worth more than 1% of this product's sales. All these increased uncertainties from both market and supply processes create challenges and pressure for the company to dynamically adjust and adopt the supply chain strategy to handle its declining product.

4.2 Case 2: infrared camera with high demand and low supply uncertainty

4.2.1 The infrared camera i5 PLC and its SC

The second case company is a market leader in thermal imaging infrared cameras. Its commercial systems division is made up of three business areas: gas detection, electronical and building diagnostics, and automation and process control. This study focused on products that are at the end of their PLC within the building diagnostics product line, the i-series and the i5 in particular. The infrared cameras have an innovation phase that is about 12 months long, and the time on the market is three to five years, with the i5 on the verge of leaving the market. The company is now experiencing a shift towards a shorter PLC, due to increasing market competition from a competitor with cheaper models. Unlike the high uncertainty from market demand, the i5 product's supply process is relatively stable. Three groups of suppliers (plastics, electronics/circuit boards and magnesium) come from both Asian and European countries. The product is pulled through production with kanban and produced to stock, after which it is later assembled to order, which corresponds to a 'leagile' supply chain.

Figure 2 EOL process at the infrared camera company



4.2.2 Changes for the SC when the infrared camera i5 moves to decline

The company has established an EOL process that handles terminating products. As Figure 2 shows, there are a number of decision points (from S1–S5) along the process. A phase out starting decision point is called 'S2 – final production' – an end date for production within 12 months is set. The main goal of the EOL process is to lower the scrap cost. The final production is also called 'build out' in the company, which refers to

'building out' the available stock of materials. After the phase-out decision is taken, a monthly discontinuation meeting is held to adjust all product-related material plans so that the phase out is reflected. Sourcing and supply will do the same towards the suppliers. While the decline occurs for a product, the company orders increasingly smaller quantities from existing suppliers in order to lower the risk of scrap cost.

4.2.3 Uncertainty challenges for SCM

Final product or 'building out' is hard to calculate a year in advance, making replenishment for components and spare parts difficult. This has an obvious impact on the level of scrap that must be taken care of when the phase-out begins. Thus, the most important key performance indicator for SCM is 'estimated scrap cost', which is recalculated several times during the 12-month period of final production. As the life cycles of electronics shorten, there is a risk that some key electronic components may be out of supply before the end of the product's life. On the other hand, suppliers giving notice of 'last time buy' for components can lead to larger purchases than actually needed; eventually the components risk becoming obsolete.

4.3 Case 3: Stapler A100 product with both low demand and low supply uncertainty

4.3.1 The Stapler A100 PLC and its SC

This company is a paper fastening products manufacturer for office users. Introduced in 1958, electric Stapler A100 is a product with a very long PLC in the company. The product is essentially made from a stapling unit and an electric motor with a plastic cover. The raw materials are mainly supplied locally, and the production is driven in batches. In fact, a lean supply chain is the company's central strategy, as the A100 product has very stable market demand and supply processes.

4.3.2 Changes for the SC when the Stapler A100 moves to decline

After being in the market more than 50 years, the Stapler A100 is in a decline phase. The company made the decision to phase out this product at the end of 2013, and the product was ended in 2014. After the Stapler A100's EOL was announced, sourcing of raw materials was scaled down in different ways depending on the relationship with suppliers. Production works with single-minute exchange of dies (SMED), kanban, and daily control boards in order to become more efficient, as is more critical when the Stapler A100 production volume is declining.

4.3.3 Uncertainty challenges for SCM

Because the decline in volume for the Stapler A100 is quite flat and stable, the raw materials are purchased from local suppliers, and component production is done in house by kanban, the supply chain strategy has not actually shifted much during the whole PLC.

4.4 Case 4: taco sauce with low demand and high supply uncertainty

4.4.1 The taco sauce PLC and its SC

This company produces and trades goods for flavouring, such as spice, spice mixes and sauces. The product taco sauce is representative of the company's products. There are several different types of taco sauce. A few taco sauces with high volume have a stable demand and long life cycles of over 20 years. But most sauces with comparatively low volumes have shorter life cycles of one or a few years. The company has around 100 customers, of which many are large supermarket chains. The demand for the different taco sauces is relatively stable and easy to predict. However, the suppliers for the taco sauce are located all over the world and the lead times are often long and unpredictable. For example, the price of many spices is affected by weather conditions. Thus, supply chain of the taco sauce is mainly characterised as 'agilean'.

4.4.2 Changes for the SC when taco sauce moves to decline

In relation to product phase-out, retail customers may tend to react strongly to signals of products being terminated immediately, as they anticipate a risk of having stock on their hands. Once a decision has been made to terminate a product, there is also a risk of unnecessary overproduction and purchasing orders being placed, which can in turn result in high inventory or even scrap. However, most of the raw materials that are used in the spice mixes for the taco sauces are used for other products too. This mitigates the consequences of the risk of obsolescence.

4.4.3 Uncertainty challenges for SCM

When phase-out of a taco sauce product is announced, the demand uncertainty increases. For example, if the company announces that a product is to be terminated within a few months, often the customers tend to stop buying the product immediately. Meanwhile, due to the regulated time windows for product phase-out in the food market, the company runs a risk of having its products replaced on the customers' shelves by a competitor's brand.

5 Analysis and discussion

We return to our research questions, starting with the analysis of the uncertainties and related challenges when products transition from the mature to the decline phase of the PLC.

5.1 Uncertainties and challenges when products enter the decline phase

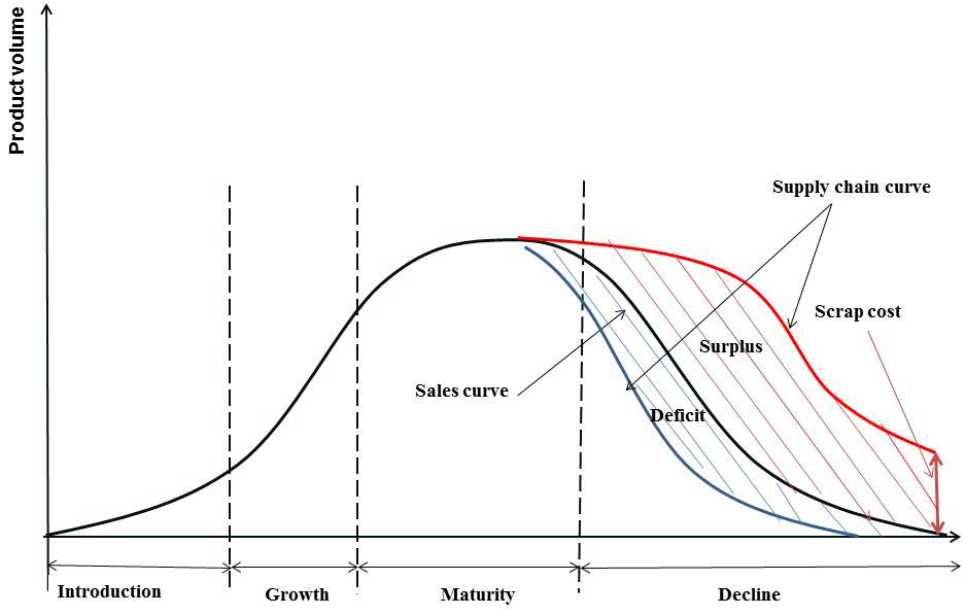
The four case studies reveal that the management of supply chains faces various challenges from ageing products, declining volumes and changes in demand and supply uncertainty.

Most obvious are the challenges for firms to adapt the supply chains to the declining volumes in the later part of the PLC, as described for instance by Anderson and Zeithaml

(1984) and Hsueh (2011). The challenge of adjusting supply to lower demand is mainly a question of how to reduce the capacity in existing supply chains, both internal and external, without resulting in either surplus or deficit capacity. In practice, this can be done by consolidating manufacturing and suppliers to single locations to maintain high-capacity utilisation and continuing to benefit from economies of scale despite decreasing volumes, as described in the telecom case. The camera and taco sauce cases show how new product generation successively overtakes the supply chain of the declining product, which limits the need for redesigning the SC.

One challenge experienced in the case firms is the difficulty of communicating information about phase-out and termination decisions between the product owners and supply chain managers when products enter the decline phase. Three case companies reported that the difficulties associated with communications could result in both mistimed and misinformed decisions, as well as in delayed actions in response to the decisions.

Figure 3 Inventory risks in the decline phase (see online version for colours)



A general difficulty associated with declining volumes relates to inventory levels, which tend to increase in relation to sales volume. Reasons include both purchasing quantities and production batches, which may be difficult to reduce. For the purchasing quantities, both contractual agreements with the suppliers and inbound transport efficiency can make it difficult to reduce quantities. Similarly, setup times in production can impede reducing batch sizes to match sales volumes. Overall, these difficulties tend to increase the days in stock, resulting in capital being tied up longer and an increased risk of scrap, as illustrated in Figure 2. Here, the risk of scrap is related to the product characteristics. For products with more uncertain supply, such as Taco Sauce, the risk of scrap is higher when finished products are left in stock. However, the innovative RBS3G product has a much more complicated manufacturing process and customised production. In addition,

the RBS products are sold in much higher volume worldwide, compared to the other case products. If the product's SC cannot respond as quickly as the sales volume declines, there is a huge risk that overproduction will cause high inventory and scrap costs of not only components that cannot be used for other products but also finished goods. Comparatively, a functional product with a long life cycle, like the Stapler A100, is not so sensitive to excess production and scrap costs, because the volumes are low and stable. The risk of holding too much or too little inventory is illustrated in Figure 3.

An important aspect in the phase-out of many products relates to warranties and the supply of spare parts. The companies for the RBS3G, infrared camera and Stapler A100 all stated that this is one of the challenges that needs to be addressed. Naturally, the need for warranties and supplying spare parts is linked to product characteristics – spare parts need not be considered after the taco sauce's EOL.

5.2 Challenges due to changes in demand and supply uncertainty

Most of the problems with products in decline in the case companies can be attributed to changes in supply and demand uncertainty, something not found in most previous studies of PLC and SCM (Birou et al., 1998; Doha et al., 2013; Lee, 2002).

Overall, the case products' demand and supply uncertainties become increasingly stable as the products progress from introduction to maturity, in line with Anderson and Zeithaml (1984). The matching supply chain strategy is considered to be relatively more 'lean' for all case products, although each of them has different product characteristics. This tendency is illustrated as dashed arrows in Figure 4.

The cases indicate that every product possesses its own characteristics and uncertainties that change along the life cycle. As the products start to decline, the characteristics of the four selected products progress in different directions. The RBS3G product demand uncertainty increases compared with its mature phase, due to the risk of customers either increasing order volume for their own buffer inventory or ceasing purchases completely in favour of newer products. Meanwhile, supply uncertainty also grows due to such factors as reduced supplier numbers, production consolidation and related changes in logistics. The infrared camera's supply uncertainty is also higher than in its mature phase, since the key electronic components may end life before the product's EOL, whereas the infrared camera's demand uncertainty stays almost the same as in the mature phase. The taco sauce producer runs a considerable risk that the customer may choose another brand of product and drop the taco sauce before the end of its life, thereby increasing that product's demand uncertainty, but the product's supply uncertainty in the decline phase does not change substantially in comparison with the mature phase. The stapler product's product characteristics undergo almost no change, and both demand and supply uncertainty continue the trend towards lean, as it has had quite a stable market demand and simple supply chain during its more than 50 years' long life cycle.

There are some potential challenges related to uncertain customer behaviour towards the end of a product's life cycle. Here, the case companies displayed two opposite types of behaviour. The producer of the taco sauce reported that many retailers tended to stop buying the product before it was terminated, as they anticipated a risk of having an obsolete product in stock. The telecom company for RBS3G mentioned that its customers may increase orders after the 'last time buy' announcement, because they may choose to

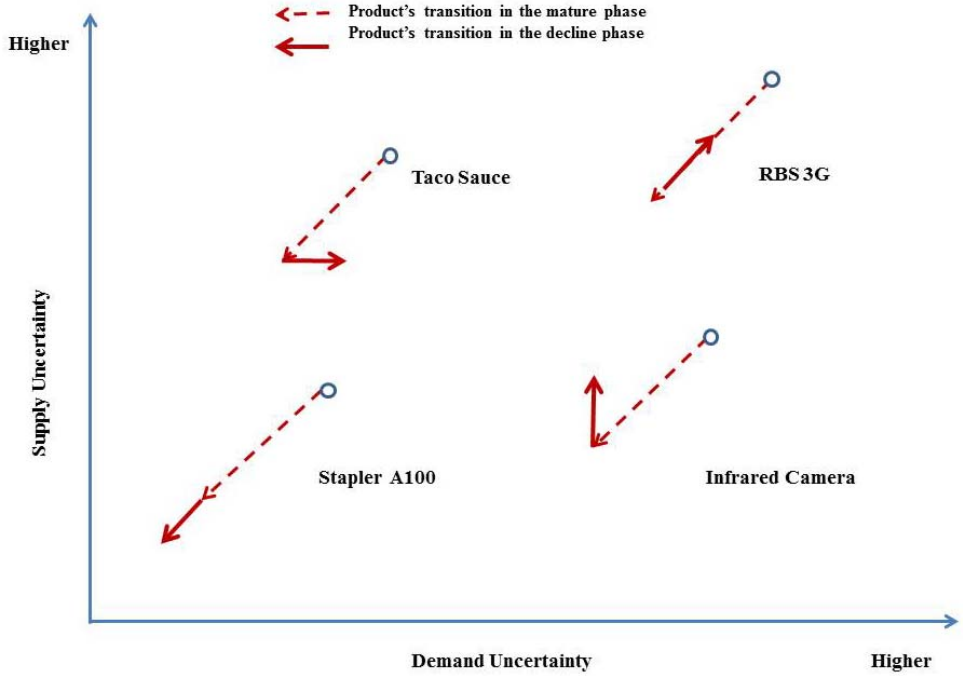
increase their own buffer inventory. It is, however, also possible that the customers will be more interested in the new product than the ageing one. Consequently, the supply chain has to act agilely to adapt to this more unpredictable market demand.

Using a modified version of Lee's (2002) uncertainty categories, we summarise in Table 2 the changes in product demand and supply uncertainty when the selected products move from the mature to the decline phase.

Table 2 Changes in uncertainty when products move from the mature to the decline phase

	RBS 3G	*IR camera*	*Stapler A100*	*Taco sauce*
Demand uncertainty				
Unpredictable demand	*Increasing*	Unchanged	*Decreasing stably*	*Increasing*
High product variability	Unchanged	Unchanged	Unchanged	Unchanged
Supply uncertainty				
Production process	Unchanged	Unchanged	Unchanged	Unchanged
Supply source uncertainty	*Increasing*	*Increasing*	*Decreasing stably*	Unchanged
Lead time uncertainty	*Increasing*	Unchanged	Unchanged	Unchanged

Figure 4 Demand and supply uncertainty change differently when the products switch from mature to decline, depending on product characteristics (see online version for colours)



The case analysis shows that three of the four selected products' characteristics (either demand or supply uncertainty) change from relatively stable to unstable when switching from mature to decline. It seems that a major turning point occurs when products switch

from the mature to the decline phase. The changes are illustrated by the solid line arrows in Figure 4.

5.3 Aligning supply chain strategies with product uncertainties in the decline phase

The second research question concerned the implications that the changing uncertainties and challenges of products in the decline phase have for the design of the product supply chains. The need to match product characteristics and supply chain functionality has long been established in the supply chain literature, e.g., that innovative products are best managed by responsive supply chains and functional products by efficient ones (see Fisher, 1997; Selldin and Olhager, 2007). But since our study specifically investigates the impact of uncertainty, we combined the uncertainty framework of Lee (2002) with the supply chain strategies elaborated by Christopher et al. (2006) to build up a generic uncertainty framework for supply chains. The resulting framework, displayed in Figure 1 in the Theoretical Framework section, illustrates how demand and supply uncertainty relate to the lean, agile, leagile and agilean supply chain strategies. Classifications of this type by necessity grossly simplify the complex nature of companies and products, yet can nonetheless be used for discussing, in general terms, the challenges the firms are facing.

Our main interest is, however, not what kind of supply chain is feasible for the studied products, since the selected cases are not representative of the different situations. Our core question is instead how the transition from the mature to the decline phase changes demand and supply uncertainty, and specifically how this change in turn requires changes in the existing supply chain strategies defined by the framework.

Figure 4 shows that each case product's demand and supply uncertainty changes when the product's life cycle phase switches from mature to decline. Three of the four cases display a deviation or break from the ongoing process towards less uncertainty when the products enter the decline phase; the exception is the product Stapler A100. This result implies that managers must dynamically adjust and align the supply chain for a product even during the later phases of the PLC. It is also evident that the pattern differs between the products, which indicates that the changes in uncertainty could concern both demand and supply. Thus, the requirements to change the supply chains depend on the product characteristics. Our case descriptions also show that the companies use different approaches to manage the challenges of matching the supply chain strategy to changing product demand and supply uncertainties.

After using the uncertainty framework to analyse each case product's characteristics at the switch from the mature to the decline phase, we conclude that supply chains should be redesigned as follows to meet the changes in demand and supply uncertainty:

- The RBS 3G product needs a more agile supply chain in the decline phase, when both demand and supply uncertainty are higher than in the mature phase.
- The infrared camera requires a more agilean supply chain, because its supply uncertainty is higher in the demand phase than in the mature phase.
- Taco sauce needs a more leagile supply chain in decline, because the demand uncertainty is higher than when it is in the mature phase.

- The Stapler A100 could keep a lean supply chain continuously, as the product's uncertainties in both demand and supply do not change when its PLC switches from mature to decline.

Whether the identified changes to the supply chains are worth making is a question that requires a cost analysis for redesigning the supply chains and a comparison of the potential benefits of matching the uncertainties in the decline phase with a feasible supply chain strategy. This is a subject for further studies.

6 Conclusions and contributions

Our study dealt with the relationship between PLC and supply chain strategies, focusing on the changes in the later phases of the product life. More specifically, our study concerns how product demand and supply uncertainties change during the decline phase and what this means for the applied supply chain strategies. We compared products in four companies that experience different levels of uncertainties during the decline phase. Due to the explorative character of the study, we have chosen to formulate our conclusions in terms of propositions for further research.

In addition to the obvious need to limit supply capacity due to diminishing demand during the decline phase, three out of the four cases display a need for further changes to the supply chain strategies during the decline phase due to increased uncertainties in demand and/or supply. The need to redesign the supply chains dynamically leads us to suggest the following proposition:

P1 There is a need to change product supply chains in the decline phase due to increased supply and demand uncertainties for the product.

The different cases, however, reveal some differences between the products. The uncertainties and the successive needs for change to supply chains during the decline phase are most pertinent for the complex and innovative products with a short life cycle (such as telecom equipment), where there is greater need for more agile supply chains. Conversely, the functional product, representing low demand and low supply uncertainty, does not need any adjustments to the lean supply chain in the decline phase except for the obvious capacity limitation. The other two cases display situations where the characteristics of demand and/or supply uncertainties call for more agilean or leagile supply chains. This leads us to the following proposition:

P2 The need to adapt product supply chains during the decline phase relates to the character and magnitude of the supply and demand uncertainties for the respective product. The different changes in demand and supply uncertainties correspond to the need to choose a relatively more agile, leagile, agilean or lean supply chain.

Adjusting the product supply chain during the decline is, however, not without costs for the firm. The need for changes to an existing product supply chain during the decline phase includes not only limiting the capacity (e.g., consolidating manufacturing and suppliers) but also managing the uncertainties in supply and demand that occur, e.g., by increasing safety stock, surplus capacity or flexible manufacturing. All these changes represent costs that must be evaluated against the possible benefits of adapting the supply chains to the greater uncertainties, benefits that can include a lower quantity of obsolete

material, more prompt deliveries and sufficient capacity. Changing the supply chains is valuable for both to keep them efficient and to adapt to customer needs. This means that the identified uncertainties represent a supply chain dilemma and trade-off situation for the firm that should be explored in future research. The reasoning leads us to suggest the following proposition:

P3 The decline phase represents a trade-off between the costs of changing the product supply chain to better manage the greater uncertainties and the costs and limitations of maintaining the existing supply chain.

In line with the findings that demand and supply uncertainties differ between products, the fourth proposition becomes:

P4 The trade-off between changing and maintaining the product supply chain during the decline phase depends on the character and magnitude of the supply and demand uncertainties.

This paper provides three scientific and practical contributions. First, we have extended the well-established insight of supply chain design claiming that 'one size does not fit all' (Shewchuk, 1998). Our explorative study does not contradict this perception, but rather illustrates that one size does not even fit one! We have shown that managers must dynamically change the supply chain strategy along the PLC. Specifically, there is a need to align supply chain strategies with the changing product uncertainty when the product moves into decline, in order to reduce inventory cost.

Secondly, we have shown the value of using the matched supply chain strategy frameworks from Fisher (1997), Lee (2002) and Towill and Christopher (2007) when analysing the need to redesign the supply chain for products in the decline phase.

A third value of the paper is that it highlights the need to setup a dynamic conceptual model that integrates current supply chain theory and PLCs in the decline phase, which can help industrial firms handle the challenges presented by shortening PLCs.

As avenues for further research, we propose to validate and test the propositions in additional empirical studies. We also emphasise the need to expand the scope of our study and to develop a dynamic uncertainty framework for supply chain strategy that covers the entire PLC.

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