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Decision model for product rollover in manufacturing operations

Abstract

The purpose of this study is to investigate critical decisions when planning for product rollover at a manufacturing company, and how to organize these decisions. A literature review and a case study are used to develop a decision model. The findings indicate that product rollover can be organized in a five-phase decision model. The research quality is strengthened by a structured literature review, but it can be argued that more empirical research is needed for validation. For researchers, this paper contributes with the identification of critical decisions and a model for product rollover. For practitioners, the study highlights the need to acknowledge the importance of product rollover and its role as a competitive weapon. In earlier studies product rollover has mainly been investigated from a market perspective, so that this study contributes by investigating the issue from a manufacturing perspective.

Key words: Product rollover, Product introduction, Product elimination, Manufacturing

Paper type: Research paper

1 Introduction

Manufacturing companies operate in a constantly changing environment. Segmentations have been made with two categories of products being identified: those which compete over the lowest price, and those who compete on other values (Fisher 1997). However, more recent research has moved away from this dichotomy, and advocates approaches that combine the benefits of the two extremes (Christopher et al. 2006, Jüttner et al. 2007, Piller et al. 2004). The increased pace of innovation is placing companies under constant pressure to decrease time-to-market (TTM) and to shorten product life cycles. Thus, the pressure is increasing on the performance of new product development (NPD), which has recently received considerable attention in research (e.g. Banduchi 2013, Khan et al. 2012, Feng et al. 2014). Besides an innovative and appealing physical product, the market introduction must also be managed in an appropriate manner for the product to succeed (Hultink and Robben 1999). Despite the awareness of decreased TTM and shorter product life cycles, research about decisions pertaining to introduction the of new, and the removal of old products is scarce, and there are currently no overviews summarizing the research field.

If a new product replaces an old one in the market, the product introduction and elimination must be considered simultaneously (Lim and Tang 2006). This process is called *product rollover* (Billington et al. 1998). It has, in fact, been argued that introduction is the most important element of analysis, as not all product introductions coincide with product elimination (Carrillo, 2005). The decision to look at rollover, and both product elimination and introduction in this paper, is a result of the data extrapolated from the empirical research. In general, there are two different potential strategies, solo rollover and dual rollover. The former implies that the old product is already sold out when the new product is introduced. By contrast, the dual rollover aims at providing both the current and the new product simultaneously for a while, in order to successively phase out the old product while phasing in the new one. Solo rollover, when executed flawlessly, entails low rollover cost, but is on the other hand associated with high risk and is therefore preferred when market risk is low (Koca et al. 2010).

Product rollover can be viewed as a competitive weapon, if managed efficiently (Wan et al. 2007). The issue is related to production ramp-up, which has its roots in the late 1990's (Surbier et al. 2014), but both the old and the new product need to be considered in order to obtain a complete picture. If the old product is taken out of production too early, before the new product is launched, it will result in profit losses and customer dissatisfaction (Lim and Tang 2006). Similarly, if production continues for too long, there will be an excess of products and they may become obsolete, leading to markdowns, sales, and lost revenue. Furthermore, if the production of the new product starts too early, an inventory carrying cost occurs until the market is ready for the new product (Hill and Sawaya 2004). For companies with short product life cycles, this becomes even more pressing, as the situation repeats itself more often over time. Accordingly, a better understanding of this dilemma might be pivotal for companies in such a competitive market.

There are several real-life examples of the importance of product rollover. Ashton-Tate, Ford, and IBM are examples from the literature that are still mentioned with regard to unsuccessful product rollover (Billington et al., 1998). Failure can also be expensive, for example, Sony Ericsson reported a €133 million loss in their 2003 first quarter report, mainly due to product rollover problems. For a product rollover to be successful, it has to be managed appropriately throughout the supply chain. The ultimate goal with a product rollover is to

successively fill the supply chain pipeline with a new product and introduce it to the market on time. Simultaneously, the pipeline must be emptied of old products which need to be eliminated from the market on time (Billington et al. 1998). Additionally, to successfully conduct a product rollover in the market, a product rollover has to be conducted in a successful manner at the manufacturing company (Bilginer and Erhun 2015). The execution in production is vital, and to succeed with the product rollover in this context, it is essential to plan the product rollover in advance. Product rollover planning can be carried out in the early stages in the NPD, while the execution takes place in the final stage. In particular, a synthesized model containing guidelines from early planning to actual rollover would benefit practitioners, while also providing researchers with an overview of the entire process.

As to better understanding product rollover, the purpose of this study is to investigate critical decisions implicit in the production at a manufacturing company. This issue has been examined through a literature review and a case study of a Swedish manufacturing company from the power products industry. Empirical data has been collected mainly from semi-structured interviews with key informants representing functions involved in the product rollover, and two document studies

The remainder of this paper is structured as follows. The research method is described in more detail in Section 2, after which the findings of the literature review and case study are presented in Sections 3 and 4. Thereafter, the findings from the literature review and case study are analyzed in Section 5. In this section, the proposed decision model also is presented. Finally, the research is concluded in Section 6.

2 Research method

The aim of this study is to investigate critical decisions in the context of planning for a product rollover at a manufacturing company, and how to organize these decisions. This issue has been examined through a literature review and a case study of a Swedish manufacturing company from the power products industry. In essence, theoretical and empirical knowledge with regard to critical decisions was collected and compared. Thereafter, the decisions were organized into a decision model.

2.1 Research strategy

The lack of validated knowledge regarding the targeted research area calls for a qualitative analysis. This enabled the researchers to collect numerous forms of data and to examine it from various angles, in order to construct a rich and meaningful picture of a complex, multifaceted situation (Leedy and Ormrod 2001). In order to reinforce the qualitative research approach, the combination of a literature review and case study was selected as the most appropriate methods for this study (Lekvall and Wahlbin 2001).

The literature review was carried out in two phases. The first was to explore the existing theory in order to provide a context (Williamson 2002) and the second phase related to the literature in the context of this study. Since the issue of product rollover could be addressed as a separate process or as part of NPD, two separate literature reviews were conducted and subsequently merged to create a complete picture.

The case study approach was chosen for two main reasons. First, it was necessary to dig deeper into this field to understand the decisions and the planning of a product rollover. Second, a case study allowed the researchers to investigate this less explored process in its

natural setting (Jacobsen, 2002). By asking explorative questions such as why, what, and how meaningful and relevant, data was generated, based on the understanding achieved through interviews in actual practice (Leedy and Ormrod 2001, Jacobsen 2002, Voss et al. 2002).

The case company used in this study was chosen for two reasons. First, the company has an explicit process for introducing new products and eliminating old ones. Second, the company has experienced several challenges associated with conducting a product rollover, and therefore showed an interest in this study, in order to further investigate and organize the decisions.

Combining a rigorous literature review with a single case study is a strategy aimed at both capturing state-of-the-art knowledge, as well as providing a context for emerging empirical findings. This strategy is derived from Eriksson's (2015) explanation of the relationship between the role of research and the existing body of knowledge.

2.2 Data collection

The literature review used keywords that were combined into search algorithms using Boolean logic, and completed in a stepwise process. Since the issue of product rollover could be addressed as a separate process or as part of NPD, two search algorithms were employed to maximize the inclusion of relevant literature (Table 1). Each paper that was found was carefully evaluated in terms of relevance to the research and cross-checked for additional references, so as to obtain the most appropriate literature for the current research.

The database used to search the literature was Scopus, one of the most comprehensive full-text databases of peer-reviewed journals. The keywords were used as a selection criterion for the topic (Title, Abstract and Keywords); no time delimitations were adopted in this review. Only papers published in scientific journals were taken into consideration, since they are considered as validated knowledge (Podsakoff et al. 2005) and have the highest impact. In order to preserve the internationality of the result, only English-language papers were included.

The samples for both the search algorithms were reviewed in two stages. In the first stage, the abstract was reviewed, leaving 33 papers for the first search algorithm, and 106 for the second search algorithm still in review. In the second stage, the entire paper was reviewed. A total of 23 papers for the first search algorithm and 4 for the second search algorithm passed this screening (Table 1).

Insert Table 1 about here.

In the case study, semi- structured interviews were used to gather empirical data from the case company with regard to the product rollover. The questions were formed to obtain answers on how the case company works with product introduction and elimination, which decisions they take regarding the planning of product rollover, and the challenges associated with a product rollover. The semi-structured interviews enabled follow-up questions (Williamson 2002), given the researchers the opportunity to obtain relevant and important information, since employees from different functions were interviewed and had different views of the process. A total of 12 interviews were performed, and the length of each interview was approximately one hour.

2.3 Data analysis

The data collected was qualitative in nature and a corresponding method of analysis was used. Initially, the researchers transcribed the records of the interviews and summarized the main points. A summary of the interviews is presented in Table 2. Note that the first interview has the number zero, because it was used to understand the empirical setting and to prepare for further studies. This made it possible to identify relationships between the respondents' statements (Williamson 2002). Furthermore, the summarized data was categorized according to the three topics, that is how the case company works, which decisions are taken regarding the product introduction and elimination, and what the challenges are when introducing a new product, while eliminating an old one. The categorization made it possible to compare the data, recognize relationships and draw conclusions (Saunders et al. 2009).

Insert Table 2 about here.

The analytical techniques used in this study were essentially pattern matching (Yin 1994). The researchers searched for gross matches and mismatches, in which even an 'eyeballing' technique is sufficiently convincing to draw a conclusion (Yin 1994). Based on the data analysis, several decisions were identified in both the literature review and the case study. The decisions were compiled into five categories that embraced 15 decisions. Pattern matching was used to compare the decisions from the literature review and those from the case study, which had the same meaning (Yin 1994). This laid the foundation for merging those decisions that could validly be merged and also to organize the decision into a decision model.

3 Literature review

The literature review revealed a number of important decisions to consider. These were grouped into four categories, including: (1) Volume, which is concerned with production volumes of the new and old product, as well as spare parts during rollover; (2) Capacity, which is related to volume but concerned with production capacity during rollover; (3) Timing, with a focus on what strategy to use and when to introduce and remove products from the market and production and (4) Inventory, which revolves around the inventory levels of new and old products during rollover and the future demand of old products after the rollover. Below, the decisions identified are described in each respective category. A summary is available in Table 3.

Insert Table 3 about here.

3.1 Category 1: Volume

The first decision in the Volume category is to decide how much to produce of the new product during the product introduction (Abernathy and Baloff 1973, Carrillo and Franza 2006, Özer and Uncu 2013, Shen et al. 2014). Before introducing a new product to the market, it is necessary to match production volume with demand forecasts. This, in turn requires cross-functional planning and jointly developed production and marketing plans. The volume will fluctuate during the product introduction, which is needed to align with a determined production start-up pattern. Incompatibly developed plans may result in undesired consequences. If demand exceeds supply, consequences such as opportunity costs, direct expenses and order cancellations can occur. In the contrary case, there is a financial risk associated with tying up assets, and excess inventory may lead to obsolete products because of modifications or lost sales.

The second decision in the Volume category is to decide how much to produce of the old product up to the elimination date (Avlonitis 1983). Avlonitis (1983) developed a framework for the implementation of product elimination. When the decision is taken to eliminate a product, the marketing program up to the elimination date is determined. It is decided what volume of the old product needs to be produced in order to satisfy residual demand, including backlogs, the completion of contracts and expected demand up to the elimination date. Matching the production volume with the residual demand is necessary in order to avoid leftover inventory of finished products.

The third decision in the Volume category is to decide how many spare parts to produce (Avlonitis 1983, Kim and Park 2008). Before eliminating a product, it is necessary to decide how many spare parts to produce, so as to satisfy future requirements. The number of spare parts required depends on the set warranty period and agreements on spare parts availability.

3.2 Category 2: Capacity

The first decision evident from the literature review in the Capacity category is to decide on the required production capacity (Carrillo and Franza 2006, Bilginer and Erhun 2010, Li et al. 2014). Prior to the start of production of one new product replacing another, decisions regarding production capacity need to be considered. During a product rollover, the demand for the old product ramps down, while the demand for the new product ramps up. Thus, capacity planning needs to be managed according to this pattern. Planning for the optimal capacity entails trade-offs. Setting the capacity too high implies costs for idle capacity, while setting the capacity too low forces the company to build up inventory before product introduction or end up with backorders. The capacity also needs to be distributed appropriately between the old and new product. An important factor to take into account when planning for the capacity during a product rollover is whether the old and new product will be produced with the same manufacturing equipment. If so, the production capacity will be restricted during the product rollover. Using separate manufacturing equipment allows more flexible capacity utilization.

3.3 Category 3: Timing

The first decision in the Timing category is to decide what rollover strategy to use (solo or dual) (Saunders and Jobber 1994, Billington et al. 1998, Lim and Tang 2006, Koca et al. 2010, Liang et al. 2011, Liang et al. 2014). It is of major importance to consider the launch and elimination timing in relation to each other. This means deciding whether to apply solo or dual product rollover in the market. If carried out successfully, a solo rollover implies lower costs than a dual rollover. However, the downside is that a solo rollover implies higher risks, and is therefore preferable when demand is stable. The risks of a solo rollover include an excess of inventory of the old product, that the old product is out of stock or that there is a delivery delay of the new product. While dual rollover is associated with other risks, such as cannibalization, that the old product simply takes over the demand for the new one. Another possible scenario is that customers delay their purchase of the old product in the hope of buying it at reduced price in efforts to clear the old stock.

The second decision in the Timing category is to decide when to launch the new product in the market (Hultink and Robben 1999, Klastorin and Tsai 2004, Savin and Terwiesch 2005, Krankel et al. 2006, Lim and Tang 2006, Calantone and Di Benedetto 2007, Ramachandran and Krishnan 2008, Liu and Özer 2009, Bilginer and Erhun 2010, Koca et al. 2010, Li et al. 2010, Su and Rao 2011, Yang et al. 2011, Wang and Hui 2012, Ke et al. 2013, Özer and Uncu 2013, Bilginer and Erhun 2015). One decision that has a significant impact on the success of a

product introduction is the timing of the market launch. As indicated above, introducing a product too early may lead to cannibalization of the old product's demand. Rushing the introduction under time pressure may also affect the quality and performance, because of insufficient and/or poor development of the new product. On the other hand, introducing the new product too late may lead to lost market share, because of decreased novelty and competitor entry, which could also harm the brand. Introducing a product during low season reduces production and logistics complexity, but introducing it during high season gives the product more attention.

The third decision in the Timing category is to decide when to eliminate the old product from the market (Avlonitis 1983, Lim and Tang 2006, Liu and Özer 2009, Koca et al. 2010). During a product rollover, it is necessary to decide when to eliminate the old product, setting a specific date. Doing so too early may lead to a loss of potential customers for that product. Conversely, delaying the elimination may result in lost sales. Koca et al. (2010) suggests that this decision is strongly related to the choice of rollover strategy.

The fourth decision in the Timing category is that of deciding when to start the production ramp-up (Abernathy and Baloff 1973, Carrillo and Franza 2006). When the market introduction date of the new product is set, the manufacturing company needs to decide when to start the ramp-up in relation to the market introduction. This needs to be considered cross-functionally between marketing and production. The optimal point in time to start the ramp-up is affected by the decision on how much to stock in inventory before market introduction.

The fifth decision in the Timing category is when to end the product elimination (Avlonitis 1983, Koca et al. 2010). The timing of the elimination from the market affects the timing of manufacturing the final build of the old product. When the elimination date is set for the old product, the manufacturing company needs to decide for how long the production of the old product should proceed in order to satisfy residual demand i.e. when the elimination is ended in terms of production.

3.4 Category 4: Inventory

The first decision found in the literature review in the Inventory category is the inventory level of the new product during the product introduction (Calantone and Di Benedetto 2007, Li et al. 2010, Li and Graves 2012, Shen et al. 2014, Bilginer and Erhun 2015). Capacity shortages are a problem when it comes to product introductions, and companies sometimes have difficulty satisfying the unexpected demand for the new product. This can be solved by delaying the launch and thereby being able to build up a greater initial inventory. Another possible scenario is that the old product stocks out before the demand is fulfilled, and has to be substituted by the new product. Using a new product, as a substitution for the old product will affect the inventory levels and thereby disturb the initial planning quantities. Li et al. (2010) have developed a model to facilitate the planning of inventory levels and to balance the risk of shortages and excess inventory.

The second decision in the Inventory category is to decide on the inventory level of the old product during the product elimination (Avlonitis 1983, Billington 1998, Koca et al. 2010, Li et al. 2010). Before eliminating a product, the manufacturing company needs to ensure that the inventory level concerning finished products is sufficient to fulfill remaining demand. Building up too high an inventory level of the old product may lead to excess inventory when the new product is launched. It is therefore necessary to plan for appropriate inventory level of the old product during the product elimination. Excess inventory of the old product might

force the company to delay the introduction of the new product, until the old product is sold out, so as to avoid leftover inventory.

The third decision in the Inventory category is to decide how much material and how many components are needed to satisfy residual demand for the old product (Avlonitis 1983). Before eliminating a product, the manufacturing company needs to ensure that the inventory levels concerning raw material and components are sufficient to fulfill the residual demand.

4 Case study

The case company was founded in 1689 and is now the world's largest manufacturer for several types of gardening machines. Four divisions comprise the company group, and the case company division is a world leader in the forest and garden segment. The targeted end-customers are professionals and demanding consumers with stringent requirements and expectations of product performance and quality. The case company division operates globally and has production facilities, sales offices and distributors worldwide.

The product range that the case company division offers entails wheeled products such as garden tractors, electric products such as robotic mowers, and petrol-powered handheld products such as chainsaws. Within the petrol-powered handheld product range, new products and product upgrades are developed and introduced frequently to the market. The product development process of new products, or product upgrades, that the case company uses is called the product creation process (PCP).

The PCP is a well-developed and structured development process for developing new products for the market. The PCP has been developed to ensure a common framework for defining, developing, and launching new products. During the ramp-up phase, the product rollover is executed and when new products are introduced, old ones must be eliminated in an appropriate manner. The elimination process, on the other hand, is not as developed as the PCP and can easily be neglected during the development process. There is considerable focus on the front-end of the PCP and a lesser focus on the back-end. The elimination process is a separate one which reoccurs every year. It comprises several steps involving several segments of the company. The first step is to suggest a list of products to eliminate, called the elimination process cycle (EPC). Six months prior to the last planned production day of a product, the production planners and material planners are start to act. However, previous projects have however ended up with a lot of obsolete material due to an inadequate elimination process. Not considering the introduction and elimination of products simultaneously during the development process has led to severe problems for the case company which was left with unsold products.

The case study revealed a number of necessary decisions which were grouped into five categories to provide a clear overview of the identified decisions. The decision categories included: (1) Volume, (2) Capacity, (3) Timing, (4) Inventory, and (5) Communication. Below, the identified decisions are described in each respective category. A summary is provided in Table 4.

Insert Table 4 about here.

4.1 Category 1: Volume

The first decision emerging from the case study in the Volume category is to decide on the volume for the new product. Before introducing a new product, during the development

stage in the PCP, a predicted sales forecast of the new product is sent to production, in order to plan for required production volume during the production ramp-up. The first proposed volume is established in the project proposal and is thus very uncertain. Accordingly, it is necessary to constantly update expected demand. How steep the production ramp-up needs to be, depends on customers demand and when exactly the ramp-up is started.

The second decision in the Volume category is to decide on the volume for the old product. Before eliminating a product, it is decided how much to produce during the elimination, so as to satisfy residual demand. When the level of demand is known, the material planner and production planner consider the remaining components in stock. It could be that the demand for finished products is less than remaining components. In such a case, the cost of discarding components must be weighed up against producing enough products to utilize all components. If the demand for finished products is more than remaining components, a similar deliberation has to be made. The decision aims at making the customers sufficiently satisfied and at the same time avoiding obsolete components.

Spare parts are available ten years from purchase the date, but are usually the suppliers' responsibility. As such, the company does not currently make the decision on how many spare parts to produce. A buy/make decision has been made previously, highlighting that certain decisions can be outsourced to another actor in the supply chain. In terms of product roll-over, the result is that this parameter does not need to be considered.

4.2 Category 2: Capacity

The single decision in the Capacity category is to decide on production capacity based on sales forecasts. Before product introduction, during the PCP, the sales forecast is delivered to production for a decision regarding the production capacity required to satisfy the demand. The capacity must be allocated appropriately between the two. If the expected demand for the new and the old product exceed available capacity, it may be necessary to take action. Potential actions may, for example, include delaying the product introduction or accelerating the product elimination in order to release capacity.

4.3 Category 3: Timing

The first decision identified in the case study in the Timing category is to decide when to launch the new product. A decision on when to launch a new product is first proposed early in the process, in the project proposal. However, this proposition is built on very vague arguments and is just a rough estimate. At the beginning of the product development, before the investment gate, a decision on a more specific and reasonable launch date is made.

The second decision in the Timing category is to decide on the elimination date of the old product. In the EPC, one decision is to decide on elimination date of the old product, based on risk and season patterns. Before setting a specific elimination date, inventory audits are conducted to investigate whether it is possible to sell out in time. If it seems that the inventory level of the old product is high, it may be necessary to postpone the elimination date. The elimination date, in relation to the introduction of a new product may be affected by factors such as novelty and ambiguity. If customers are reluctant to buy the new product until it is accepted in the market, it is advisable to delay the elimination of the old product.

The third decision in the Timing category is to decide on the phase-out strategy. In the EPC, one decision is to determine the phase-out strategy. That means deciding whether to

have full availability of the old product until the elimination date, or to sell out beforehand. This decision is also dependent on the number of products in stock.

The fourth decision in the Timing category is to decide when to start the production ramp-up. During the product development, a launch meeting is held in which the project leader, R&D, supply, material planning, production planning and responsible for industrialization all participate. In that meeting, a decision is made on when to start the production ramp-up. When the manufacturing pilot test is approved, the ramp-up starts. A defined batch is produced and a follow-up of the result is conducted, with the sequence continuing until the production process is complete and full-scale production is reached.

The fifth decision in the Timing category is to decide when to end the production ramp-up. The date for ending the production ramp-up should be considered, in order to ensure that the product is fully available for sale at the decided upon sales start date. Starting or ending the production ramp-up too late may result in a late product introduction in the market. Moreover, having a longer ramp-up in relation to the product introduction will enable the elimination of further errors and contribute to a more successful product introduction and thereby, on-time product introduction.

The sixth decision in the Timing category is when to start the production elimination. The aim of this decision is to determine when to start the ramp-down of production volume, in order to successively eliminate the old product from production. Starting the production ramp-down too early may lead to insufficient finished products for residual demand, while the converse may lead to a surplus of products.

4.4 Category 4: Inventory

The first decision found in the Inventory category is to decide on the inventory level for the new product. Before product introduction, a decision is made as to required inventory level of finished products before the sales start. Early on in the product development process, product management, sales and supply agree on the necessary inventory level and on production requirements.

The second decision in the Inventory category is to decide inventory level for the old product. When setting the elimination date, it is important to decide on the inventory level of the old product in order to satisfy residual demand. If the old and new product are intended to be manufactured simultaneously for a certain period and the capacity is not sufficient, the company may be forced to produce the old product in advance and build up inventory for the remaining demand.

The third decision in the Inventory category is to decide on how many components are needed to fulfill residual demand for the old product during product elimination. When the remaining production volume of the old product is set, a decision is made on how many components are required in the inventory, in order to be able to produce the necessary volume. The material planner is involved six months before elimination date, so as to optimize inventory and reduce obsolete material. It is considered whether to replenish components, so as to satisfy the demand or simply to make the customers satisfied enough, by producing just below the level of prevailing demand, to avoid replenishing missing components.

The fourth decision in the Inventory category is on how much material and how many components are needed to fulfill the demand for the new product during the product

introduction. This decision should ensure that sufficient components are available during the product introduction to avoid any disturbances due to a lack of material. A lack of components during the production ramp-up may delay the product introduction, and is thus an additional factor to consider when planning the product introduction.

4.5 Category 5: Communication

The single decision in the Communication category is to decide on the communication plan of the product rollover throughout the organization. At the company challenges regarding communicating product rollover were identified. The decision to eliminate a product is, however, not communicated in an appropriate manner throughout the organization, which causes severe problems for the case company. Thus, a decision on how to communicate, when to communicate, and who is responsible for the communication of the product rollover at the production, needs to be made.

5 Analysis

5.1 Critical decisions to consider

In this section the decisions derived from the literature review are compared with those from the case study in accordance with the formed categories.

5.1.1 Category 1: Volume

In the literature review, three decisions were found in the category Volume. The first decision, ‘decide how much to produce of the new product during the product introduction’, is equivalent to the corresponding decision in the case study, ‘decide on volume for the new product’. The description of the former decision is more informative and indicates the time perspective concerned. Thus, this decision will be selected as a basis proceeding.

The second decision, ‘decide how much to produce of the old product up to the elimination date’, is equivalent to the corresponding decision in the case study, ‘decide on volume for the old product’. However, since the elimination date could have a different meaning according to the case study in question, the description of the decision to proceed with will be clarified: ‘decide how much to produce of the old product during the product elimination’. According to the case study, the case company may choose to have full availability of the old product until the elimination date or sell out before.

The third decision, ‘decide how many spare parts to produce’, is only found in the literature review and will thus remain unmodified. In the case study, the supplier mainly supplies spare parts. As such, they were treated as the main product and not a spare part.

The analysis of decisions in the first category (Volume) yielded a total of three decisions:

- (1) Decide how much to produce of the *new* product during the product *introduction* (V1)
- (2) Decide how much to produce of the *old* product during the product *elimination* (V2)
- (3) Decide how many spare parts to produce (V3)

5.1.2 Category 2: Capacity

In the literature review, one decision was found in the Capacity category. The decision, ‘decide on the required production capacity’, is equivalent to the corresponding decision in

the case study, 'decide on the production capacity, based on sales forecasts'. The description of the former decision will be selected to proceed with, because of its simplicity.

The analysis of the decisions in the second category (Capacity) yielded just one decision:

- (1) Decide on the required production capacity (CA1)

5.1.3 Category 3: Timing

In the literature review, five decisions were found in the Timing category. The first decision, 'decide what rollover strategy to use (solo or dual)', is only found in the literature review and will thus remain unmodified. The reason that no similar decision is found in the case study could be that the case company considers the issues of product introduction and elimination separately.

The second decision, 'decide when to launch the new product at the market' is equivalent to the corresponding decision found in the case study, 'decide when to launch the new product'. To avoid any ambiguities, the description of the former decision will be selected for further use.

The third decision, 'decide when to eliminate the old product from the market', is equivalent to two corresponding decisions found in the case study, 'decide on phase-out strategy' and 'decide on elimination date of the old product. The two latter decisions in combination, answer the question of whether to provide full availability of the product or sell out before the set elimination date. In short, this is about deciding when to eliminate the old product. Thus, the decision found in the literature will be selected for further use.

The fourth decision, 'decide when to start the production ramp-up', is equivalent to the corresponding decision found in the case study, 'decide when to start the production ramp-up'. The description of the decision is the same and is thus selected to proceed with.

The fifth decision, 'decide when to end the product elimination', is only found in the literature review, but the decision will be proceeded with since it is considered important for satisfying residual demand (Avlonitis 1983, Koca et al. 2010).

Further decisions that were only found in the case study are, 'decide when to end the production ramp-up' and 'decide when to start the product elimination'. These decisions will be proceeded with, since they are considered important.

Deciding when to end the production ramp-up is important in order to comply with the market introduction. Ending the production ramp-up too late may result in a delayed product introduction into the market and insufficient volumes to satisfy the demand. Setting the end date of the ramp-up too early may result in personal stress, which in turn could result in mistakes being made.

Deciding when to start the product elimination is important to consider, in order to successively eliminate the old product in the production. Starting the product elimination too early may result in insufficient products to satisfy residual demand, while starting too late may result in surplus stock.

The analysis of decisions in the third category (Timing) yielded seven decisions:

- (1) Decide what rollover strategy to use (solo or dual) (T1)
- (2) Decide when to *launch* the *new* product in the market (T2)
- (3) Decide when to *eliminate* the *old* product from the market (T3)
- (4) Decide when to *start* the production *ramp-up* (T4)
- (5) Decide when to *end* the production *ramp-up* (T5)
- (6) Decide when to *start* the product *elimination* (T6)
- (7) Decide when to *end* the product *elimination* (T7)

5.1.4 Category 4: Inventory

In the literature review, three decisions were found in the category Inventory. The first, ‘decide on the inventory level of the new product during the product introduction’, is equivalent to the corresponding decision the case study ‘decide on inventory level for the new product’. The description of the former decision is more informative and indicates the time perspective concerned. Thus, this decision will be selected for further use.

The second decision, ‘decide on the inventory level of the old product during the product elimination’, is equivalent to the corresponding decision found in the case study ‘decide on the inventory level for the old product’. The description of the former decision is more informative and indicates the time perspective concerned, so that it will be selected for further use.

The third decision, ‘decide how much material and how many components are needed to fulfill residual demand for the old product during product elimination’ is equivalent to the corresponding decision found in the case study, ‘decide how many components we need to purchase to fulfill residual demand for the old product’. The former decision is more informative, also considering material, and is thus selected for further use.

One further decision that was only found in the case study is ‘decide how much material and how many components that needed to satisfy demand for the new product during the product introduction’. This decision will be proceeded with, since it is considered important, in order to ensure that sufficient components and material are available during the product introduction, so as to avoid disturbances. A lack of components and material may result in a delayed product introduction.

The analysis of decisions in the fourth category (Inventory) yielded four decisions:

- (1) Decide on the inventory level of the *new* product during the product *introduction* (I1)
- (2) Decide on the inventory level of the *old* product during the product *elimination* (I2)
- (3) Decide how much material and how many components are needed to fulfill residual demand for the *old* product during product *elimination* (I3)
- (4) Decide how much material and how many components are needed to fulfill the demand for the *new* product during the product *introduction* (I4)

5.1.5 Category 5: Communication

In the case study, one decision was found in the Communication category. The decision is ‘decide on the communication plan of the product rollover throughout the organization’, and it is important due to the challenge of communicating product rollover appropriately. Thus, this decision will be selected for further use. Similar issues have been identified when changing production systems (Oudhuis, 2004), and it is notable that it was not identified in product rollover. It seems reasonable to assume that such decisions become more pressing if the change in products is coupled with an increased change in production.

The analysis of the decision in the category Communication yielded just one decision:

- (1) Decide on the communication plan of the product rollover throughout the organization

5.2 Decision model

In the previous section, a total of 16 decisions in five categories were presented. Four of these decisions have been identified as beyond this study's scope, but this does not imply that they are unimportant for this study. On the contrary, they set the prerequisites for subsequent decisions and define the context. Thus, they are important to consider when planning for a product rollover at the market before taking any other decisions when planning for a product rollover in the production. Hence, they will be considered as the initial phase, Phase 0. Apart from Phase 0, there is no definitive answer yet as to the order or reciprocity of the phases, and the model presented is in no way final. When discussing the different decisions in this section, abbreviations presented above are used. The decision model discussed below is illustrated in Figure 1.

Insert Figure 1 about here.

5.2.1 Phase 0

Deciding on the timing of the launch (T2) in and elimination (T3) from the market is the precursor to the other decisions. The decisions convey when the new product must be introduced to the market and when the old product must be eliminated. This timing, in turn, defines the product rollover strategy (T1). This strategy, on the other hand, can be decided on before deciding when to introduce the new product or eliminate the old on (Koca et al., 2010). It depends on the approach an organization chooses.

Introducing a product too early, may cannibalize the old product's demand (Lim and Tang 2006, Koca et al. 2010). Introducing a product too late, on the other hand, may result in loss of market share due to decreased novelty and competitor entry (Calantone and Di Benedetto 2007, Li et al. 2010, Özer and Uncu 2013). Eliminating a product too early, may lose potential customers for that product. Eliminating a product too late, on the other hand, may result in the new product suffering from lost sales (Lim and Tang 2006, Liu and Özer 2009, Koca et al. 2010). Thus, in order to succeed with the product introduction and elimination on time, the production needs to be prepared so as to satisfy the market by introducing new products and eliminating old products in an appropriate manner. It is necessary to plan, so that production is suitable in relation to the prerequisites set for the market. To achieve this, the planning of the product rollover in the production is vital.

In the case study, one of the challenges was that of communicating the elimination of the old product. This communication is not conducted in an appropriate manner at the case company and has caused severe problems. Moreover, it is also important to communicate the product introduction parallel with the elimination, that is the product rollover (CO1). This should ensure that all parties involved have the appropriate information regarding the product rollover. The fourth decision (CO1) is one that extends to many different levels in the organization and may therefore be considered somewhat beyond the scope of this study. For example, the communication of when to eliminate or introduce a product from or to markets is beyond this study's scope. However, the communication regarding when to eliminate or introduce a product in *production* is within this study's scope. Hence, the communication plan (CO1) should be considered throughout the entire planning of product rollover in terms of production.

In closing, since the four decisions discussed above define the conditions when planning for a product rollover in production, they are regarded as an initial phase, Phase 0, in the decision model (Figure 1).

5.2.2 Phase 1

Depending on the timing of product introduction to the market, the inventory (I1) and production volume (V1) of the new product during product rollover need to be decided on in the production facility at the manufacturing company. Before the new product is introduced to the market, the manufacturing company needs to decide on the desired inventory level at the sales start. This entails the manufacturing company having either inventory before the sales start, or starting sales as the production ramps up. Full inventory before the sales start contributes to higher inventory cost on the one hand, but ensures that the demand can be satisfied more effectively. Moreover, the latter alternative entails lower inventory cost, but increases the risk of not being able to satisfy the demand (Li et al. 2010).

In addition, before introducing a new product to the market, it is necessary to match production volume (V1) with demand forecasts (Abernathy and Baloff 1973, Carrillo and Franza 2006, Özer and Uncu 2013, Shen et al. 2014). This requires jointly developed production and marketing plans, in order to align the production start-up pattern with the demand during the product introduction. Incompatibly developed plans might have undesirable consequences. If demand exceeds supply, opportunity costs, direct expenses and order cancellations can occur. If supply exceeds demand, consequences such as financial risk tying up assets and excess inventory might lead to obsolete products, material, and components due to lost sales (Li et al. 2010). Thus, deciding on the volume and inventory level of the new product during the product rollover in the production provides a foundation for deciding on the ramp-up time in relation to the market introduction.

To succeed with the elimination of the old product in the market, the process needs to be conducted at the right time in terms of production (Avlonitis 1983, Koca et al. 2010). In order to succeed with the elimination and to empty the pipeline from products, by the elimination date at the market, the manufacturing company needs to decide when to end the elimination (T6) in production. This entails the manufacturing company deciding when to start the elimination in production (T7), in order to empty the pipeline by the elimination date at the market.

In closing, since the four decisions discussed above are crucial, prior to the following decisions, they are placed in the first phase, Phase 1, in the decision model. This phase consists of two parts; the upper part includes decisions regarding product *introduction* while the lower part includes decisions regarding product *elimination* (Figure 1).

5.2.3 Phase 2

When the volume and inventory level during the product rollover is decided, it is possible to decide the ramp-up time in relation to the market introduction. The start of production ramp-up is affected by the decision on how much to stock in inventory before the market introduction. Thus, planning the initial inventory level before introducing the new product to the market will set the foundation for production ramp-up. The goal is to introduce the new product to the market at a certain time. In order to do so, it is necessary to decide on the inventory level needed at the sales start and the volume during the product rollover. Now, knowing how much to produce of the new product and how much to fill the inventory before the sales start, it is possible to plan the ramp-up to achieve a successful on-time product introduction. Thus, the start (T4) and the end (T5) of the production ramp-up needs to be

considered cross-functionally between marketing and production. The optimal point in time to start the ramp-up, as mentioned earlier, is affected by the decision on how much to stock in inventory before market introduction and the volume during the rollover (Abernathy and Baloff 1973, Carrillo and Franza 2006, Özer and Uncu 2013, Shen et al. 2014). Depending on the inventory level and volume of the new product, the production ramp-up time may vary in relation to the market introduction. Therefore, deciding when to start the production ramp-up is extremely important.

When the start and end of elimination in production is decided, the manufacturing company needs to decide on the inventory level (I2) and how much to produce of the old product (V2) during the rollover (Avlonitis 1983, Billington 1998, Koca et al. 2010, Li et al. 2010). The goal is to empty the pipeline of old products by the elimination date. To do so, the decision on when to start (T6) and when to end (T7) the elimination in production at the manufacturing company is vital. When the elimination period has been set, it is important to decide on the volume of the old product that needs to be produced during the elimination. This is to satisfy residual demand, including backlogs, completion of contracts and expected demand up to the elimination date (Avlonitis 1983). Matching the production volume with the residual demand is important in avoiding leftover inventory of the old product. Moreover, the manufacturing company also needs to ensure that the inventory level concerning finished products is sufficient to satisfy the remaining demand. Too much inventory of the old product may lead to a surplus. Thus, deciding how much to produce of the old product during the elimination, and deciding on the inventory level are crucial during the product rollover. Figure 1 illustrates how the production of the old product decreases during the elimination, while the inventory of the old product still satisfies the remaining demand while emptying the pipeline. Additionally, it is necessary to decide how many spare parts to produce (V3) to satisfy future requirements. According to Kim and Park (2008), the amount of spare parts required depends on the warranty period specified and agreements on the availability of spare parts. This may delay the decided elimination time and thus prolong the elimination period.

In closing, since the five decisions discussed above are fundamental prior to the following decisions, they are placed in the second phase, Phase 2, in the decision model. Phase 2 consists of two parts; the upper part includes decisions regarding the product introduction, while the lower part includes decisions regarding product elimination (Figure 1). The decisions in the upper parts of Phases 1 and 2 can be taken before the lower parts and vice versa.

5.2.4 Phase 3

When the decisions in Phases 1 and 2 are taken, the manufacturing company has sufficient input to consider the required production capacity (CA1) (Carrillo and Franza 2006, Bilginer and Erhun 2010, Li et al. 2014). During a product rollover, demand for the old product decreases, while that for the new product increases. Hence, capacity planning is vital and needs to be managed according to this pattern. The capacity needs to be distributed accurately between the new and old products. Excessively high capacity entails higher costs than needed (Li et al. 2014). Excessively low capacity, on the other hand, means that the company may not be able to satisfy the demand and will end up with backorders. If the new product will be produced with the same manufacturing equipment, the production capacity will be restricted during the product rollover (Li et al. 2014). If the old and new products are supposed to be produced with different manufacturing equipment, the production capacity will be more flexible. These are important aspects to consider when planning the optimal production capacity.

In closing, since the decision discussed above must be considered prior to the following decisions, it is placed in the third phase, Phase 3, in the decision model (Figure 1). Depending on the outcome in Phase 3, it may be necessary to reconsider the decisions in previous phases. If the required capacity in the production is not aligned with the previous decisions, it may be necessary to change the decisions in Phase 1 and Phase 2. Thus, the decision model is considered to be an iterative process.

5.2.5 Phase 4

From the case study it is evident that before entering the production ramp-up, it is necessary to determine how much material and components are required to produce the new product during the introduction (I4). Not considering this may delay the introduction and have severe consequences for the manufacturing company.

A similar decision regarding the old product is required. Before entering the elimination, it is necessary to determine inventory levels concerning raw material and components needed to satisfy the remaining demand for the old product (I3) (Avlonitis 1983). Not considering this may result in excessively early product elimination or too much material and too many components in inventory, which may then become obsolete.

In closing, the two decisions discussed above are placed in the last phase, Phase 4, in the decision model. Phase 4 consists of two parts; the upper part includes one decision regarding the product introduction while the lower part includes one decision regarding product elimination. The final decision model is presented in Figure 1.

6 Concluding Discussion

This study investigated critical decisions for product rollover in production at a manufacturing company. The study identified sixteen critical decisions and organized them into a five-phase decision model. The initial phase sets the condition for the next phases. It is necessary that the planning of a product rollover in the production be conducted during the NPD, so that the products are introduced and eliminated at the right time, since product rollover can be considered a competitive weapon, but only if managed successively.

The issue of product rollover has mostly been investigated from a market perspective. This study contributes by investigating the corresponding planning that needs to take place in the manufacturing process. The study contributes to the existing literature through the identified critical decisions and the decision model for planning a product rollover in production. The main practical implication of this study is that manufacturing companies need to acknowledge the importance of product rollover, since product rollover can be considered a competitive weapon if managed successively. The decision model is a basis for planning a product rollover and is developed for manufacturing companies with similar conditions to those of the case company.

The main implication for practitioners is that it is important to consider several different decisions, which can be regarded as having a certain linearity. Throughout the process, it is necessary to understand how to communicate the rollover to employees in the company. Practitioners can now use this decision model as an aid before, during, and after rollover. The main implication for researchers is that decisions can be categorized, but also interact with each other. Viewed independently, researchers can focus on inventory questions, strategic planning, and management issues. However, these also need to be understood in relation to each other, as they all contribute to product rollover.

It is evident, from the literature review, that product rollover is often thought of in isolation from other events in the company. Several researchers in related fields, highlight the importance of considering product portfolios (Hilletofth and Eriksson 2011, Talke et al. 2011, Martínez-Mora and Merino 2014, Büyüközkan and Arsenyan 2012). It is quite remarkable that this has not been taken more seriously. A more accurate depiction of product rollover is provided in Figure 2. Depending on product seasonality, two scenarios are possible. The first is that product rollover is more of a range rollover issue. In this context, many of the products are changed simultaneously to accommodate the new season. The second is that seasonality is not important for the company, and that rollovers take place continually. If the lifecycle of the products is short, we also need to consider that one product line can phase out several versions of the same product, at the same time as introducing new ones. A familiar such product is the Apple Iphone. Every year a new Iphone is introduced, but the previous model is still available on the market. Recently, a low-cost variant of the even earlier model has been made available. At the same time, rumors about future models are surfacing. Needless to say, more research is needed to better understand rollover in a more complex empirical setting.

Insert Figure 2 about here.

It is also remarkable that there is no more research related to NPD and rollover decision. NPD has a decisive impact on key management directions, such as production, marketing, and supply chain management (Gunasekaran 1998, Pero et al. 2010, Gmelin and Seuring 2014, Caniato and Größler, 2015). Especially the latter, supply chain management, should be of greater interest. It has become a cliché that supply chains compete, but, as seen with the case company, it was assumed that the supplier would take care of spare parts. It seems as if the supply chain has been forgotten in the academic debate on product rollover. A successful product introduction is reliant on several supply chain capabilities, such as production capacity and material availability. Researchers need to attend to this blind spot.

As in all research, it is important to acknowledge its limitations. This study has developed a decision model with respect to planning for a product rollover in production at a manufacturing company. It is based on a literature review and a single case study. The outcome of the literature and case were rather similar and the findings are, as such, strengthened through methodological triangulation. The single-case study also served its purpose in discovering new and important decisions to consider. Given the nature of the case study, it is difficult to evaluate to what extent these are generalizable. They do, however, show that there are still areas within the research field that have not been fully explored and that data saturation is not yet reached. The delimitations of the paper have kept the focus within the areas of sales and operations planning. However, several important decisions are linked to other functions within a manufacturing company, such as marketing and strategic decisions. There is research on how to manage these issues in a more company-wide fashion, including concurrent engineering (Ellram et al. 2007), but this was beyond the scope of this paper. Given these limitations, we argue that the paper has contributed to the literature through the review, with the novelty of a specific decision model from the case, and with empirical illustrations through the case itself. The latter especially highlighted the importance of communication for successful product rollover.

Turning to future research, this present study is explorative in nature, so that empirical data from similar and other research settings is important to continue enhancing our understanding of the specific phenomenon (Eriksson 2015). As alluded to when presenting the model, the order or reciprocity of the phases has not yet been determined. At the moment,

they are arranged in a logical manner with, for example, inventory levels and production volume being decided before considering when to start the ramp-up. However, it is not yet clear whether the phases should be linear, or whether there is a better way to order the phases. It follows that this is a useful task for further research to consider.

In research generally, there are several important questions to answer. Sometimes, they can be simplified as, for example, ‘how?’, ‘who?’, ‘why?’, ‘where?’ and ‘when?’. The focus in this research has been on ‘what’ decisions to take and also ‘when’, but only with regard to the sequence of decisions. Several important questions remain, such as how these decisions are and should be taken, who should be responsible, and why and when there should be a product rollover. These questions show that a lot of research is still needed in order to develop a coherent understanding of decision making in the context of product rollover.

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Figure 1 Decision model for a product rollover in the production at a manufacturing company.

Figure 2 Contextualized decision model for a product rollover in the production at a manufacturing company.