CHALMERS

Evaluation of Cost Associated with Variants

Within a Product Family at Stoneridge Electronics

Master of Science Thesis

JOHANNA LUNDQVIST
JOHAN LÖFGREN

Department of Product and Production Development
Division of Production Systems
CHALMERS UNIVERSITY OF TECHNOLOGY
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JOHANNA LUNDQVIST
JOHAN LÖFGREN

Department of Product and Production Development
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone +46 (0)31-772 1000

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Preface

This report is a result of a master thesis work carried out from September 2011 until January 2012, covering 30 HEC. As part of the two master programs Production Engineering and Product development at the department Product and Production development, Chalmers.

This master thesis work has been carried out at Stoneridge Electronics, as a part of the project COMPLEX Support for Operation and Man-hour Planning in Complex Production. *"The aim of COMPLEX project is to contribute to development of sustainable production systems by increased understanding of the concept of production complexity, providing means to measure, compare, and manage added complexity."* (Per Gullander, Swerea IVF)

We would like to thank the persons we have been in contact with at Stoneridge Electronics, Ericsson and Scania whom have helped us during the project and have made it possible for us to reach our goal.

A special thanks is directed to our supervisors at Chalmers University of Technology and Stoneridge Electronics, Tommy Fässberg, Stefan Höög and Thomas Andersson.

Göteborg 2012-02-10

Johanna Lundqvist   Johan Löfgren

List of Abbreviations

The following list is compiled by abbreviations used in this report.

ABC, Activity Based Costing

HMT, Thru Hole Mount

IC, Instrument Cluster

ICT, In Circuit Test

PCB, Printed Circuit Board

PLM, Product Lifecycle Management

PROM, Programmable Read Only Memory

SMD, Surface Mount Device

SMED, Single Minute Exchange of Die

TCO, Tachograph

TSU, Tachograph Simulation Unit

Abstract

Stoneridge Electronics is subject to increased mass customization. In order to meet the demands from customers more product variety has been created. Functions creating differentiation for the customer is spread out on different variants in order to save material cost, this is what drives the variants at the Surface Mount Device, SMD level. Stoneridge Electronics is faced with new variants, which leads to a larger product variety early in their production. Variants drive costs and create problems of a qualitative nature. A hypothesis is that by adding components, thus increasing the cost of products but enabling reduction of the number of variants, the variant related costs could be decreased.

In order to identify costs and qualitative problems associated with the variants of a specific instrument cluster Ursula IC at the SMD level, a picture of how the present state at Stoneridge looks like have been established. Information have been gathered from interviews, observations and documents, this have been conducted throughout the internal value chain. The major cost driver dependent on the variants at the SMD stage for Ursula IC is the variant set-up in the SMD production line.

The development and industrialization of Ursula IC have been subject to costs dependent on the number of variants that could have been reduced if fewer variants had been present. Ideas for a future state have been developed, the results rely on cost data compiled in the present state, component costs, benchmarking at two companies active in areas of interest and literature studies. This resulted in two approaches, merging of variants at the SMD level and managing the variants. The merger of variants has the potential to reduce the impact of problems identified in the study. Manage the variants, requires shorter variant set-up times and supporting system for administration activities.

Today the number of variants of Ursula IC at the SMD stage is 11, given the current variant set-up times and other variant induced costs related to the material cost, the number of variants could be reduced to 6.

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1 Introduction

In this section the background, aim and objectives, limitations and an overview of the methods used is presented.

1.1 Background

Stoneridge Electronics is a supplier to the automotive industry and part of the Stoneridge Group, which manufactures electrical and electronic components, systems and modules for the automotive industry. Stoneridge Group has 6000 employees and an annual turnover of 700 million dollars (Stoneridge Electronics AB). During 1996-97 Stoneridge Group acquired Berifors, later named Stoneridge Electronics (Stoneridge Group).

Stoneridge Electronics has 550 employees in total, with two production plants in Örebro respectively Tallinn and headquarter in Bromma. Stoneridge Electronics develops and manufactures electronic products for the heavy auto industry with customers such as Daimler, MAN, Scania and Volvo trucks. The products are developed with a close contact to the customers with focus on the customers' requirements and expectations. Such as instrument clusters and tachographs, Stoneridge Electronics also develops and manufactures Electronic control units, power distribution centres, switches and telematics. Stoneridge's corporate philosophy is based on Lean and covers manufacturing, material suppliers and supporting functions. The production is automated to a high degree and there is a focus on zero faults (Stoneridge Electronics AB).

There is a new product family with the internal name Ursula IC, this is an instrument cluster that is produced at the plant in Örebro. It is the product family studied within this project through its planed and projected lifecycle. A new instrument cluster family takes several years to develop, and Ursula IC took approximately seven years. A simplified picture of the value flow from development to after market for Ursula IC is displayed in Figure 1 Simplified value flow.

Figure 1 Simplified value flow of Ursula IC

There is a trend towards mass customization, *"producing goods and services to best meet individual customer needs with near mass production efficiency"* (Tseng & Jiao, 2001), on the automotive market in which Stoneridge Electronics is present. Therefore Stoneridge Electronics is faced with challenges of increasing demand for product variety.

Ursula IC is subject to a higher degree of mass customization compared to Stoneridge's previous Instrument clusters. For the moment the product family Ursula IC consists of 11 variants and multiple variant prototypes at the SMD level. At final assembly it is for the moment 22 variants that is anticipated to increase during the lifecycle to as much as 40. Since Ursula IC at the SMD level has many variants, it creates several activities that drive costs. The other instrument clusters produced by Stoneridge Electronics do not have as many variants at the SMD level as Ursula IC. These variants do not create any additional value for the customers compared to if all functionality could have been implemented within a single PCB, Printed Circuit Board. The variants at final assembly are hard to eliminate since the customers demand them, still Stoneridge can affect the point of differentiation in the production.

The product architecture needs to be investigated since it creates activities that drive costs along the whole product lifecycle. Different cost drivers that are associated to the number of variants at the SMD stage can be identified for product development, industrialization, production and aftermarket.

1.2 Aim and Objectives

The purpose is to research, develop and present solutions that keep costs down while allowing room for mass customization within the Ursula IC product family. The goal is to develop suggestions for a future state that is more cost-effective than the present, describing how Stoneridge can handle the costs associated with the many variants in the SMD production line. In order to achieve the purpose three objectives is stated.

Objectives

I: Determine the present projected lifecycle costs for product variants within the product family Ursula IC.

Research and analyse the present state of the product life cycle. Determine the costs associated with the different phases of the lifecycle for Ursula IC.

II: Create and introduce ideas for a future state coupled to the variants in the SMD line, which contributes to keep the lifecycle cost down for Ursula IC. A given hypothesis to be investigated is whether mergers of variants are feasible.

Research and develop suggestions for a future state of the product life cycle, based on the results from the present state.

III: - Determine how the ideas for the future state stand against the present state and what recommendation that will be given to Stoneridge Electronics.

Determine the anticipated cost reductions associated with the different phases of the lifecycle for Ursula IC. Analyse the future state and draw conclusions.

Determine if the future state in whole or in part is viable and sustainable for Stoneridge electronics.

1.3 Limitations

The study concerns one product family, Ursula IC. The focus will be on the costs created by the variants at the SMD level. A life cycle perspective will be used in order to address the costs associated within product development, Industrialization, production and aftermarket of the product family Ursula IC.

The study focuses on in house activities at the Stoneridge Electronics plant in Örebro, from incoming to outgoing goods. No alterations to the product architecture are made and the cost of implementing changes to the variant line-up is not considered. The study spans 20 weeks. Due to secrecy few actual numbers will be presented in the report.

1.4 Method

In order to achieve the three objectives several methods have been used in order to get quantitative and qualitative data. These methods are interviews, benchmarking, observations, literature study and data collection from different documents provided from Stoneridge. The general methodology of the project is simplified and displayed by Figure 2 Description of project processes, where the different project phases, problem overview, present state, future state and completion is associated with the methods used. In the beginning of the project, during the problem overview, an establishment of the problem was made. Next a description of present state was made with activities associated with the variants of Ursula IC within the different lifecycle phases. From the present state, suggestions for the future state was made and finally completion of the project.

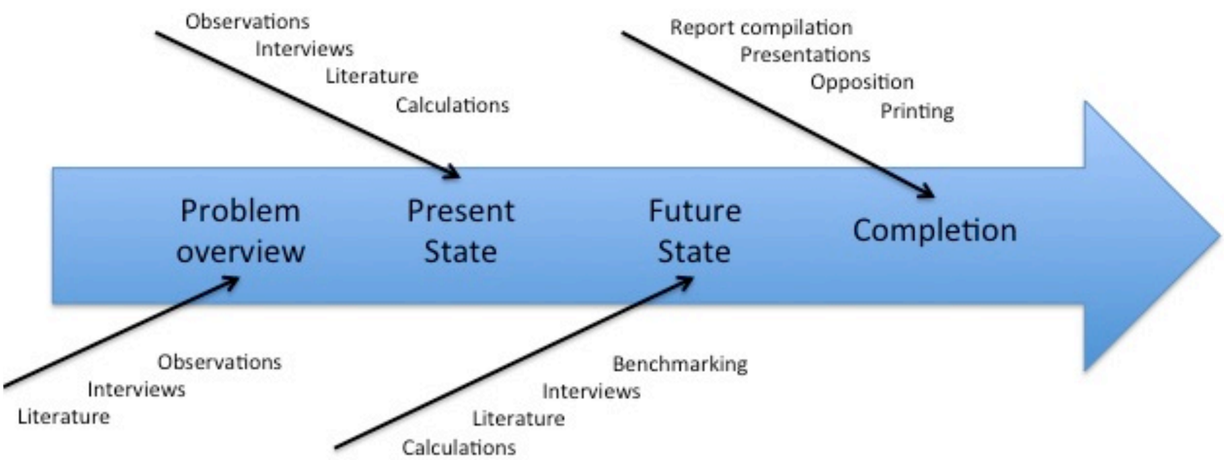

Figure 2 Description of project processes

2 Frame of Reference

This section presents reviews from literature covering topics vital to the project.

2.1 Estimate Cost Impacts of Variants

There are different approaches that can be used to assess the variety cost. There are indirect and direct approaches to assess variety costs. Under the direct approach there are volume based, Activity Based Costing, ABC and Attribute Based Costing, ABCII. The indirect approach can provide managers with a hint that something is wrong but will not provide details. The volume-based approach will spread the overhead costs evenly over all variants. Overhead costs associated with products that are subject to mass customization are not that affected by the volumes manufactured, but rather on the number of set-ups. The method ABC is developed to trace the cost associated to different products rather than costs due to product variants. This gives that ABC cannot be used solely to determine the costs of different product variants (Zhang & Tseng, 2007). *"Inspired by ABC, the variety costs root from the process (activity chain) variations due to product variety, namely process variety."* (Zhang & Tseng, 2007, p. 132)

It can be determined how product variants affect cost through studies of how the processes vary depending on the product variety. This can be facilitated focusing on the variety while relying on the principles of ABC (Zhang & Tseng, 2007). *"Variety costs are incremental to the cost of the base product and the cost of tools and fixtures to produce the base product are assumed as given."* (Zhang & Tseng, 2007, p. 138)

It can be hard to carry out an identification of variety cost drivers without using a qualitative study that covers why and where cost due to variety exist (Zhang & Tseng, 2007). *"The cost information is not required to be exact but be right in magnitude for the purpose of enabling the informed decision- makings."* (Zhang & Tseng, 2007, p. 143)

2.2 Variant Management

With product variety a company is enabled to sell their product to a higher price, but at the same time there is a risk for costs within manufacturing and development to intensify. In order to decrease the risk of such costs and thus negatively impact the profit, strategies such as delayed differentiation and modularity can be used (Desai, Kekre, Radhakrishnan, & Srinivasan, 2001).

At different stages of the product realization variety can be attained, such as during design and development, production, sales or when the product is being used. Product variety causes complexity within production systems. Assembly is regarded as a cost effective approach when a product is subject to variety. If a product family architecture has the proper design, several final product variants at the assembly will be achieved through combination of functional modules with several variants. Using a delayed differentiation approach is one way of handling the product variety in assembly systems (Hu et al., 2011).

The point of product differentiation can in a mixed-product assembly be defined as the stage where the product starts to differentiate from the other variants, thus develop its own identity. The delayed differentiation approach is important within the last stages of production in order to attain a cost effective manufacturing method. Assemble To Order, ATO have the advantage that it decreases the risk of loss from obsolescence, since finished products are often the subjects to obsolescence than the components the finished products consists of. If the product is assembled to order and then delivered it is possible by delayed differentiation to keep a stock of sub-assemblies and standardized components, which by different combinations can create a large number of product variants (Hu et al., 2011).

Delayed differentiation enables a higher degree of automation, both in the assembly and at earlier stages of the production process if standardized components are used and thus manually create the different product variants. However, in this case it is important that the set-up times is not long and costly due to for example change of components in feeders. This has been a successful principle within the white goods industry for several years. Thus obtain small economical batch sizes within high volume product families. In order to obtain a simpler material flow it may be necessary to change the design of the product to attain commonality among the components. The work to find the point of differentiation have traditionally been done by regarding a few factors such as inventory holding cost, WIP and capital investments. It may though be possible to find the point of differentiation through simulation (Hu et al., 2011).

Not all studies show that multiple producible variants that build complexity give higher variable costs in production. It has been shown that within some plants active in the automotive industry that the man hours spent on building do not necessary increase with the number options available but rather increase with option variability. Meaning that if a car is to be delivered with a range of options that are subject to variability this can create problems in manufacturing that are due to complexity. This complexity can be built away through supplying the customer with standard equipment with large coverage of options. This might lead to a higher unit cost for each product, still it can effectively reduce the complexity that production plant is subject to while maintaining the complexity of functions and product architecture (Macduffie, Sethuraman, & Fisher, 1996).

The focus of Japanese carmakers during the nineties was: *"...not so much on reducing the numbers of platforms or the options offered, but rather reducing the number of body variations per platform and the amount of parts complexity for each body style."* (Macduffie, Sethuraman, & Fisher, 1996, p. 367)

Within the car manufacturing industry the "leanest" plants were the ones that achieved the highest overall performance within the industry when 90 plants were studied between 1989 and 1990. These plants showed that flexible plants had no or low increase in variable costs due to an increase of variety of the product compared to the more inflexible plants (Macduffie, Sethuraman, & Fisher, 1996).

By using common components between several differentiated products may decrease the total manufacturing cost. Even though the direct cost for the product is increased, by for example letting several variants share a premium component instead of different components in different price classes. But due to the commonality aspect the total manufacturing cost could be lower since commonality offers a trade-off between revenue and manufacturing costs. However, the importance of the differentiation created by the component must be considered. In cases where the component does not affect the evaluation of the product performance or when the component is invisible for the customer, commonality may be something to consider (Desai, Kekre, Radhakrishnan, & Srinivasan, 2001). By sharing common components and also production processes over a platform of products, it is possible for the company to take market shares from competitors, develop their products in an efficient way and also increase the responsiveness and flexibility of the production processes (Robertsson & Ulrich, 1998).

PLM, Product life cycle management is a support system that companies can use in order to handle product information within all the life cycle phases. The ambition of such a system is to manage product information from requirement specification to scrap and recycling. However, there does not yet exist such a system that is fulfilling the ambition entirely (Johannesson, Persson, & Pettersson, 2004).

2.3 Mass Customization

Mass customization means to produce goods and services that will provide the customers with high level of variety producing near the efficiency of mass production. There is a trade-off between cost and variety, mass customization can be a mean to reduce the effect of it. In order to achieve mass customization, the product or service design needs to be flexible and the processes must be responsive and flexible. The concept of mass customization is argued whether or not it just drives existing ideas further, as for example flexibility or that mass customization is an indispensible successor to mass production (Slack & Lewis, 2008).

"More variety will make it more likely that each consumer finds exactly the option he or she desires and will allow each individual consumer to enjoy a diversity of options over time." (Halman, Hofer, & van Vuuren, 2003, p. 150)

New operations resources enable companies to meet the demands from increasing fragmented markets. For the management it is important that they have an attitude that is willing and sensitive towards the different customers' demands in order to supply customized products or services. This implies a different approach in the following activities, the production of the products or services the marketing and the design of them. In order to reduce production costs and at the same time have a wide range of variants, modularization and standardization of components is preferable, which allows standardized production processes (Slack & Lewis, 2008).

2.4 Modularity

Modularity is an efficient strategy when organising products and processes with a complex design. A system that is modular consists of independent units that composed together will function as an integrated entirety through standardized interfaces, which allow connection and communication in an easy way. The units or modules can be combined in several ways and thus create systems with modules of different functionalities. In this manner it is possible to meet several different customer demands. The modules can be manufactured in a standardized way to a low cost since the module itself is standardized (Slack & Lewis, 2008).

Modularity offers several advantages, for example a wide range of product variants that can be composed by a small set of units instead of designing a unique product for every required function. Another advantage is component verification and testing due to the functional elements corresponds to a specific unit in the product architecture. A third advantage with modularity is shorter order lead-time if products are made to order due to customer demands. By for example combine standard components in order to make different variants, or make different variants by a standard component and a customized component. The standard components can in both cases be inventoried and focus can lie on the customized component or just arrange the standard components (Ulrich & Tung, 1991).

"These Strategies has been called the mushroom approach because the product variety "mushrooms" at or near final assembly (Ulrich & Tung, 1991, p. 75)*".*

With a modularity strategy there is also some potential costs, for example increased unit variable costs due to excess capability. This often occurs when standardized components are used across product lines in order to exploit economies of scale. The design of the component must be able to correspond to the most stringent requirements. The unit variable cost for excess capability may be higher than the cost for a specially designed component for that function. Even though, to provide a complete product line with the component functionality may result in a lower overall cost. Another cost is associated with modularity and performance optimization. By reducing modularity the performance of a product can be improved, for example by reducing mass and size by function sharing (Ulrich & Tung, 1991).

2.5 Platform Management

A platform is the common basis within a product family. Therefor a platform is automatically linked to a specific product family. Platform thinking if implemented correctly throughout the companies business can be a strategy that efficiently utilizes resources while it creates room for product variety. When creating a platform for a product family it is argued that it should not be based solely on the product architecture but rather be created from how the whole value chain looks like. This means that assets such as engineering, manufacturing, branding etc. should be regarded from a wide perspective (Halman, Hofer, & van Vuuren, 2003). When planning for product platforms it is important to consider the production architecture, since it defines the range of products that is to be manufactured. For example if different models of a platform should be produced in the same line, the production architecture will decide the range of possible requirements (Robertsson & Ulrich, 1998).

"..it is generally accepted that designing a variety of products based on a product platform is an efficient way to obtain good trade-offs between product variety and costs" (Zhang & Tseng, 2007, p. 131)

Generational or platform development projects sets the foundation for future projects and have a span in design that normally takes several years (Wheelwright & Clark, 1992). Product platforms are not suitable for all types of products and or businesses since they are of a time consuming nature, which means that the first product to market on a new platform, will have a long lead-time (Halman, Hofer, & van Vuuren, 2003).

2.6 Lean Production

During the 1950:s the developments in Japan with a deep recession resulted in the development start for the TPS, Toyota Production System (Dennis, 2002). The Toyota production system is the basis for the lean production. An important principle in lean production is the elimination of non-value adding activities within the company. There are different forms of waste present namely: overproduction, waiting, unnecessary transports, excess work, excess storage, unnecessary work procedures, defects and unused creativity. Within lean production the TPS house illustrates that TPS is constructed of many different parts that creates the house, if one element is weak then the house in whole is weakened. Some of the concepts creating the house are levelled production and Just In Time, JIT. (Liker, 2009)

2.7 Production planning and control

Concepts associated with production planning and control are presented in this section.

Level out Flow

When carrying out a mixed model production or Heijunka the quest is towards production in single pieces or multiple low volume batches per day. The sequence of the different models is set according to the relation between the different volumes of the models that is demanded. The single unit model flow require very short setup times which makes it more realistic to go with low volume batches instead (Jonsson & Mattsson, 2009).

When producing according to Heijunka the production sequence is not directly derived from the current customer order but from the customer orders over time. This makes the demand levelled out over time. Since the customer orders are subject to heavy fluctuations this can stabilize the utilization of resources. The reason to produce according to a levelled out demand is that if the production flow is not levelled out and production of different models are spread out according to the demand over time there will arise problems. For example one day the workers may be subject to overtime payment but the next sent home early. This is a reason to why production plans to cover a certain amount of time, for example a day depending on patterns in actual demand and product mix. (Liker, 2009)

When regarding the production flow, one can see set-up times as waste since no value adding activity is performed. Whilst a station is down during set-ups, this would imply that large batches are better from this perspective. Still the better solution might be to target the set-ups between models or variants instead and reduce or eliminate these. This can give a higher degree of flexibility since the stock levels can be reduced and the risk of unsold goods will also be lowered. A balanced utilization of the workforce is possible and a unit that requires large amount of labour can be possible to run simultaneous with ones that require less. If the sequence is set so that the workers will have the time needed for the unit that requires a lot, is followed by one that do not requires as much labour. When the production flow is levelled out the demand that arises before the factory, in terms of goods from suppliers will be more stable, which results in the possibility for suppliers to reduce their stocks. With this decrease of their stock, the suppliers' costs will be lowered resulting in lower prices (Liker, 2009).

Flexibility
Flexibility is one of the five generic performance objectives the other are cost, quality, dependability and speed, which are general classifications where competitive factors can be arranged. Flexibility means the ability to adopt different states, and have two dimensions, range and response. These two denotes how much and how fast an operation can be changed. For example an operation is more flexible than another if it can manage more things and if it can make a change fast and to a low cost. To describe the flexibility of the total operation it can be done by consider it as a black box and regard the different types of flexibility that will conduce to the competitiveness of the total operation. Two examples are volume and product flexibility (Slack & Lewis, 2008).

WIP
Products that are between or under refinement in value-adding resources are considered as work in process, WIP. Since production processes takes time to perform work in process arises. When keeping work in process it enables different production rates in different parts of a production system. Since different processes in the production system is decoupled from each other when work in process exists. Work in process can be seen as a buffer stock since by its decoupling function it decreases the risk for disruptions in a production process to distend to another (Jonsson & Mattsson, 2009). Buffers like these hide production problems and are thus considered as costly through a lean perspective (Macduffie, Sethuraman, & Fisher, 1996).

Saw tooth Model
The saw tooth model is the common name of a principle, which arises when for example batch production is used. A simplified model of the inventory level will get the shape of a saw tooth, see in Figure 3 Saw tooth Model, and there by the name. When producing in batches the inventory level will at one occasion get an in delivery of a larger amount of goods, which will be turned over successively, this is called stock of turnover. The model is a simplification of the reality, which may not have the same time interval between the in deliveries or the same volume (Aronsson, Ekdahl, & Oskarsson, 2004). When the inventory level looks like a saw tooth, the average stock is equal to the stock level divided by two (Jonsson & Mattsson, 2009).

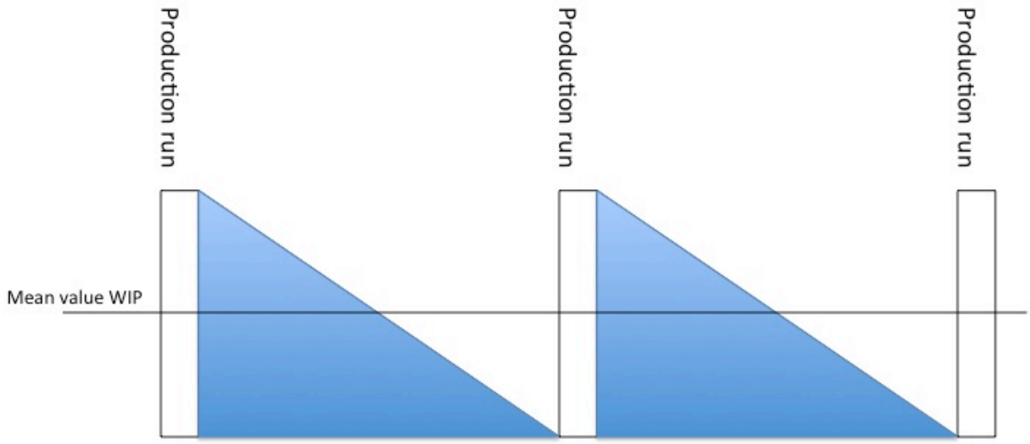

Figure 3 Saw tooth Model, picture inspired by (Aronsson, Ekdahl, & Oskarsson, 2004)

Safety Stock

A safety stock is an extra stock, which can be used in order to hedge against uncertainties of demand and supply in a material flow. It is difficult to exactly synchronise incoming and outgoing deliveries, which can effect both the time and quantity of delivery. Uncertainties depending on future demand often concerns what quantities that will be sold in the future. For example on a product level, uncertainties can be associated with volumes of unique products or the distribution of demand on different variants within a certain product family. Uncertainties associated with supply can for example be delivered order quantities, the level of scrap or delivery precision. In order to hedge for uncertainties, there exists two principals in material planning that can be used, quantity hedging respectively time hedging. Both principals cause a safety stock. The first infers to have larger volumes than what will be expected to be needed on average, the latter infers to make a delivery earlier in time than expected to be needed and is called safety lead-time (Jonsson & Mattsson, 2009).

Japanese Sea

When buffers and inventories within the production processes decreases it will reveal several problems that have not been visible before. Still these problems have existed under veil. This is called “The Japanese sea”, when the problems shows up at the surface after the water, i.e. the buffers have been decreased and thus must be dealt with (Aronsson, Ekdahl, & Oskarsson, 2004).

JIT

JIT comprises of different techniques and principles that enables to meet customer demands by producing and deliver products in short lead-times and quantities. The correct order is delivered at the right time when implementing JIT. When the customer demands is changed problems are avoided using JIT (Liker, 2009).

3 Method and Methodology

In this section the methods and methodology used is presented. First general description of the research approach and then more detailed information about the methods used, finally description of the calculations carried out in order to estimate the costs of variants.

3.1 Research Approach

A problem overview was established in order to plan how to reach the objectives stated in the introduction. This was mainly done by observations of the plant in Örebro and by contact with several people that handle and plans the production of Ursula IC and literature studies. In order to reach the first objective a description of the present state was made. This was done by interviewing several persons and collecting data from documents and observations. A production technician measured variant set-up times during production full test runs of Ursula IC, these are the basis for the variant set-up times used in the calculations.

Activities that were associated with the variants of Ursula IC was identified and evaluated. The qualitative problems were compiled and calculations of cost caused by the cost drivers were made and further analysed. During the work with the present state meetings were held with the supervisors at Stoneridge in order to discuss and validate the results, in order to minimize the risk to get a wrong picture of the present state.

The development of future state, which was the second objective, is based on the analysis of present state, on interviews, documents and benchmarking. The development department has technically validated the scenarios. The scenarios are developed considering the estimated costs of each variant, the material cost and the functions coupled to each variant. Finally the present and the future state were compared.

3.2 Qualitative and Quantitative Methodology

When a researcher collects quantifiable and empirical data in a systematic way and further analyse it, the term quantitative method can be used. It is preferable to use when large populations are to be studied. Qualitative method on the other hand, is a term for when the data collection and analysis occurs at the same time by interaction and the researcher is a part of what is being studied. A qualitative method is preferable to use when smaller populations will be studied and it have got an enhanced reputation within the last fifty years (NE Nationalencyklopedin AB, 2009). It is hard to quantify all aspects since it only can capture measurable factors, therefor a need to use qualitative methodology can exist (Ulrich & Eppinger, 2008).

Both quantitative and qualitative data have been collected. Quantitative data was primarily gathered from documents, interviews and observations, while qualitative data was primarily collected from interviews and benchmarking.

3.3 Interviews

Semi-structured interviews consist of open questions or topics that the researcher asks the interviewee with or without a specific order. The person being interviewed has during a semi-structured interview the possibility to answer the questions with substantial freedom. The semi-structured interview is a qualitative interview methodology (Patel & Davidson, 2011).

During the project process, interviews of different time lengths have been conducted. During each interview notes were taken and then sorted after relevance and type such as life cycle phases, quantified/ qualified data. When collecting qualitative data semi-structured interviews were used, but in order to collect quantifiable data the interviews had a more structured character.

The primarily purpose with the interviews in order to identify cost drivers was to ask what cost drivers is coupled to the variants in SMD and how big they are. If the person/s asked couldn't answer on how big the costs were they were asked to do estimations.

Approximately thirty persons involved in the lifecycle of the Ursula IC product family have been interviewed. The interviewees have been working at different functions throughout the organization, a list of interviewees is presented in appendices. The interviews have not been uniform of length, the timespan required for each interview have varied from a couple of minutes to a couple of hours. The interviews have been conducted either personally or via mail. A snowball approach have been used in some of the interviews, since some of the interviewees have answered some questions and then sent us towards others in order to get an answer they have not been able to answer themself.

The purpose of the different interviews has been to obtain information about the present state and further also for the development of the future state. From the design and development centre in Bromma information concerning cost drivers in the development phase and aftermarket was obtained during a visit and via mail. And from the plant in Örebro information concerning cost drivers primarily associated with the industrialization and production phase was collected.

3.4 Benchmarking

To capture best practices, benchmarking can be used in order to analyse and evaluate the own organization against another (Boxwell, 1994).

Two visits have been carried out one at Ericsson in Borås and one at Scania in Södertälje. The purpose of the visit at Ericsson was mainly to see their production plant and gain input to the development of the future state since they are also producing products using SMD technology. The purpose with the visit at Scania was to assess their platform and modularisation approach to product structure. And to get more general information on how they manage to handle product variety. The visit at Scania was more of an interview and a visit to one their research lab. The visit at Ericsson was intended to focus on production while the visit at Scania was focused towards research and development.

3.5 Calculations

In this section the calculations required to conduct the Present and Future state are described.

3.5.1 Calculations Present State

Calculations to complete the Present state is explained in this section, the method is inspired by Activity Based Costing and the ideas of (Zhang & Tseng, 2007).

Development

Estimations were made on the size of the administration costs regarding revision changes that were considered as variant dependent due to the variants at the SMD stage. The estimation of the costs is calculated according to:

$$Admin = h * p * l \tag{1}$$

$$Admin = Administration\ cost$$

$$h = Number\ of\ hours\ spent\ per\ person\ due\ to\ variants$$

$$p = Number\ of\ persons\ needed$$

$$l = Internal\ debiting\ rate$$

The same internal debiting rate is used for all white-collar workers in Bromma considered. The test costs are complied from an interview with a test engineer in Bromma.

Industrialization

Based on interviews, estimations were made on the size of the cost that were considered as variant dependent due to the variants at the SMD stage. From the industrialization manager estimations of costs due to sync meetings in the industrialization work required because of the variants were obtained. From a production technician estimations on the time required for the line software were gathered. From a production engineer the extra cost due to the variants in the ICT were given.

Production

The volumes used in the calculations are based on the predicted customer needs for the year 2017 when the Ursula IC product family are predicted to be produced at full pace. There are eleven variants at the SMD level that is regarded for these calculations. The volumes for variant 10 and 11 is estimated based on the volumes of the corresponding variants in Heidi IC today and the assumption that the TSU will stand for ten per cent of the volume of variant 10, since this approximate relation is observed for the other TCO/TSU variants. The volume level and card number of the different variants is displayed in Table 1 Volume levels.

Variant	Card nr	Volume level	Model
1	500487/1R17	Low	TCO
2	500487/2R17	Low	TSU
3	500487/3R17	Medium	TCO
4	500487/4R17	Low	TSU
5	500487/5R17	High	TCO
6	500487/6R17	Medium	TSU
7	500487/7R17	High	TCO
8	500487/8R17	Medium	TSU
9	500487/9R16	Medium	BUS
10	500487/10R17	Medium	TCO
11	500487/11R17	Low	TSU

Table 1 Volume levels

One variant, number 7 is the highest volume variant, the other variants are sorted into low, medium and high volume variants. For these variants the number of set-ups required per week is projected using knowledge attained through interviews and discussions about how the planner for the SMD line is likely to act on both the low and high volume variants. This have given the pattern that the calculations will be carried out according to that low volume variants are produced once a week, every two weeks, every month, every two months and twice a year. For the medium volume variants the runs looks like the following, four times a week, three times a week, twice a week, once a week, every two weeks, once a month. For the high volume variants it is the following, once a day, four times a week and three times a week.

Stoneridge do not know how the order frequency will look like from the customer, and the demands can vary from day to day and week to week between variants. Therefor the pattern on how the variants will be produced is not yet determined since all facts are not present yet. An assumption is made that the demand for a variant is equally distributed over a year. The most likely run frequency scenario determined is based on the planned production volumes and is the following: The high volume variants, number 7 and 5 will most likely be produced once every day and this is expressed by Stoneridge. The low volume variants are likely to be produced once a month and twice a month. This is according to their volumes and due to the fact that they must be produced more than once a year to avoid the risk of being scrapped when revision changes occur. It is also not economically feasible to produce them to often, still the demand is assumed to be equally distributed over a year. The medium volume variants are then assumed to be produced with a run frequency in-between the low and high volume variants with regard to their volumes. The run frequency gives a certain batch size corresponding to the volumes of each variant.

Set-ups

Due to the fact that if only one variant been present the highest volume variant do not pay for any variant set-ups, in this case variant 7. The other variants pay for two set-ups except variant number 5 that is a high volume variant and pays for one set-up. In the calculations below this is called pay factor.

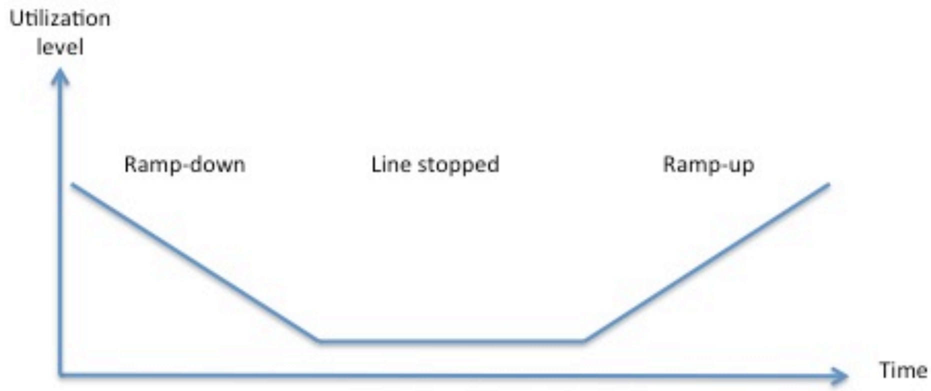

Figure 4 variant set-ups

The variant set-ups consist of three phases, ramp-down, line stopped and ramp-up. A picture describing these different phases that a variant set-up consists of related to the utilization level of the SMD line is shown in Figure 4. The reason to the ramp-down and ramp-up phases is that Stoneridge empties their SMD line in-between variants. The total equivalent stop time, TES for the line is calculated according to:

$$TES = LS + (RD + RU)/2 \tag{2}$$

$$TES = Total\ equivalent\ stop\ time$$

$$LS = Time\ for\ line\ is\ stopped = 6\ minutes$$

$$RD = Ramp - Down\ time$$

$$RU = Ramp - Up\ time$$

The variant set-up times is evaluated in three time scenarios A, B and C. The first A, consume only the time for which the line is stopped. In this scenario the line is stopped only during the change of components and no ramp down or ramp up phase is needed, since it is possible that it is not necessary to empty the line in order to do a set-up in the future. The ramp-down and ramp-up time is zero in this case. The Second time scenario B, is due to the possibility to empty the line on one side first and run one variant setup on one side of the card and another on the other side. Or if it is possible to make a gap in the ramp-down and ramp-up phases in-between the different variants. The third scenario C, is what it takes to do a variant set-up today. Including the current ramp-down, total stop and ramp-up phases.

The set-up costs are then calculated according to these categories both as a whole year aggregated set-up costs and per card. The aggregated set-up cost during a year for a specific variant, set-up time and run frequency is calculated according to:

$$Sc = St * Lc * RF * W * PF \tag{3}$$

$$Sc = Set - up\ cost$$

$$St = Set - up\ time$$

$$Lc = Line\ cost = direct\ Machine + operator + overhead$$

$$RF = Run\ frequency\ per\ week$$

$$W = Production\ weeks\ per\ year = 50$$

$$PF = Set - up\ pay\ factor$$

Since the set-up times and the run frequency vary, this yields a matrix. The set-up cost per card is given by dividing entries in the matrix by the production volume for the variant per year.

The Batch sizes corresponding to different Run frequencies are calculated according to:

$$B = V/(W * RF) \quad (4)$$

$$B = Batch\ size$$

$$V = Variant\ volume$$

WIP

The WIP, here considered to be the storage of cards between the SMD and the HMT line, are calculated depending on the number of production runs per week and are displayed as a projected mean value that. This mean value will probably be most accurate for the low volume variants if produced in larger batches than the customer requires at the specific time so that there is a safety stock. Since the WIP approximation is just a straight line between the production runs displayed in Figure 3 Saw tooth Model. Mean number of cards in WIP is calculated according to:

$$Cn = B/2 \quad (5)$$

$$Cn = Mean\ number\ of\ cards\ in\ WIP$$

$$B = Batch\ size$$

Mean time for cards in WIP is calculated according to:

$$Ct = D/2 \tag{6}$$

$$Ct = Mean\ time\ for\ cards\ in\ WIP$$

$$D = Days\ between\ runs$$

Mean value of WIP is calculated according to:

$$WIP = Cn * Cv \tag{7}$$

$$WIP = Mean\ Value\ of\ WIP$$

$$Cv = Card\ value$$

Capital Cost of WIP is calculated according to:

$$WIPc = WIP * i \tag{8}$$

$$WIPc = Capital\ Cost\ of\ WIP$$

$$i = discount\ rate$$

The cost of WIP also contains the storage costs of cards for the low volume units since these might be subject to storage, due to larger batches than the short-term demand are able to cope with. These batch sizes are due to high set-up costs. The assumption that two racks will be stapled on top of each other is done. The product family would have required a safety stock to work against even if there had been only one variant in SMD the mid and high volume units that are expected to have a faster turnover will not drive any cost for the surface area of the plant that it occupies. The cost used is a footprint cost that normally is used to calculate the cost of the space production lines occupy in the factory. WIP cost for plant surface is calculated according to:

$$WIPs = (As * Ac)/2 \tag{9}$$

$$WIPs = WIP\ cost\ for\ plant\ surface$$

$$As = Area\ of\ base\ surface\ of\ rack$$

$$Ac = Cost\ for\ surface\ area$$

Revision Changes

The costs present in production due to revision changes are based on interviews with production engineers and technicians. The assumption that it is normal and expected to see two revision changes a year in the production is done. This is calculated by first considering the total time spent on Line software, Production administration, Vision test Software and ICT and further multiplied with the internal debiting rate for production engineers.

Scrap

An estimation of scraping cost that has been done based on, that the whole stockpile of low volume variants, that are in the repair loop, are written of as scrap two times a year. The measuring of the amount of cards present from each product family in the repair loop started year 2011 week 41. The estimation of how many cards at the SMD level for Ursula that will be present in full production is made by a comparison with the current predecessor to Ursula, which is Heidi. Still, the low volume variants, 4, 1, 11 and 2, comprise only the yearly volumes estimated at full production Since the cards at SMD level are presumed to have the same possibility of ending up in the repair loop independent of variant it is likely that about one per cent of the cards entering the repair loop will be low volume variants. However since these cards are less likely to exit the repair loop they might stock up here and then be scrapped when a revision change occur.

3.5.2 Calculations Future State

In order to find scenarios for possible mergers a chart over functions on each variant was used in order to compare similarities between variants, also the planned production volumes and component cost were considered. Requirements for the future state solutions are that the functions must be able to be combined and the cost must be economically feasible.

The component cost for each card had do bee gathered and broken down according to each component. The different scenarios of reducing variants required analysis of what components that were common and not between different variants. These had also to be quantified and the cost of each component needed to be related to the right component. For example in a TCO/TSU merger the TCO variant has components that the TSU does not have and vice versa. For this and the other purposes of the calculations for the future state different formulas in excel was used. This gave an additional component cost of each merger for each variant type included in the merger. This additional cost was then related to the specific volume that it concerned. This total extra cost of material for each merger was then related to the savings in production by using the same model for calculations as in the present state but with the new volumes. When conducting these calculations it was assumed that the number of runs of the merged variants would not increase past the number of runs for the variant in the merger with the highest amount of runs per week due to the mergers.

In order to see how many variant set-ups that must be saved for each merger to be economically feasible, a table was created. Based on the setup times of today and the projected production volumes of 2017. The extra material cost due to the mergers is related to the cost of revision changes, surface cost for WIP and set-up cost. The capital cost of the WIP is not considered here.

4 Present State

The present state at Stoneridge Electronics is presented, with a focus on the activities that are affected by the variants at the SMD stage. The section is divided according to the different life cycle phases of the Ursula IC. In each part descriptions of the activities are presented as well as qualitative problems linked to the activities and quantitative results from the calculations.

4.1 Product Description

Ursula IC is an instrument cluster produced for a customer active in the heavy transport industry. Today it consists of eleven variants in the SMD line and 22 variants at final assembly. Ursula IC is today in a ramp up phase to replace the previous instrument cluster Heidi and will go in full production from year 2014. Today product cluster 1 is produced and during next year cluster 2 will be phased-in to replace cluster 1. After cluster 2 there is a cluster 3 that is planed. There are prototypes of more variants both at the SMD level but also at the final assembly. There is a trend towards larger displays on the market and Ursula IC captures this. The Ursula IC is a complex instrument cluster that incorporates complexity and a long development lead-time. The Ursula IC is regarded as a long lifetime product.

The variants are driven of the functions, which means that the functions that the customer demands have been developed and spread out on different variants in order to minimize the material cost.

The different variants are separated according to different functions that are demanded by the customer. Such functions are support for different display sizes, support for rear view camera, prep for internal or external speaker. Regulation differs on different markets, this have resulted in the division of TCO and TSU variants. TCO means that the variant is equipped with a tachograph unit, while TSU means that the variant have a tachograph simulation unit. A picture of a high tech Stoneridge Electronics instrument cluster is displayed in Figure 5 Instrument Cluster.

Figure 5 Instrument Cluster (Stoneridge-Electronics, 2011)

4.2 Development

Based on interviews with configuration management and a design engineer the results concerning the development of the different variants are compiled. The functions that are to exist on the PCB card is developed first and then a master schedule is created containing all the functions available in the product family at the electronic level. From the customer wants, for example which engine the instrument cluster is to work with, the variants are created using an automated variant creation tool. After this stage component placement drawings are created this is done as an external outsourced activity that consumes approximately one hour per variant. When a revision change occurs this procedure needs to be repeated if it is a hardware change.

Qualitative Aspects in Development

A great risk with increased variants in SMD is that developers can lose their connection to some degree with the product, through not recollecting what variant that are equipped with what functions and styling. Revision changes at the SMD level can imply that a component is swapped for another component after which all the variants need to be reviewed. This means that the developer needs to get the old Bill of Material, BOM, and compare to the new one in excel post by post. When there are many variants it is stated that the risk of missing a fault increases dramatically. When updating and creating a new revision the correct version of for example an excel file or drawing needs to be used, this is a problem since there is no PLM system present at Stoneridge Electronics today. This enables simultaneous work, which may lead to confusion when there are multiple versions of the same document created simultaneously by different persons.

Cost Estimations in Development

When a larger revision change is made that consist of both hardware and software, a number of people are required to meet, approximately such a change will take a day for five persons to administer after the individual work is done. This results in an approximate cost per revision change that is dependant on the number of variants, though this is also due to the complexity of the product.

Qualitative Aspects in Testing

These results are from an interview with a test engineer and a design engineer. Multiple tests are conducted on the instrument clusters during the development phase.

When it comes to the validation phase the number of variants in the Ursula product family builds complexity, since the tests are expensive and the different functions spread out on different variants. This makes it impossible to get a good coverage of functions by performing the different test on just one variant. Different functions can behave differently on different variants; still the functions are only tested once. Customers have a desire that all aspects and functions shall be tested for all variants but they are not prepared to pay the price.

When planning the tests Stoneridge utilize the benefits of cross functional groups in the sense that they sit down from both development and testing and create a validation plan. This in order to determine what to test for each function and on which variant it should be tested within, the tests are mapped to functions. The tests are not full fractional tests but instead Stoneridge uses worst case testing, so that the validation of function is carried out on the variant where it is mostly likely to behave in an unwanted manner. This makes the validation process and the product less robust since all functions are not tested in all the variants were they are present meaning the risk that cluster can end working in a strange way increase

During the planning of the test phase Stoneridge keep in touch with the customer so that the customer is content with the tests performed. Since validation is dependent on demands from the customer that the clusters delivered shall be tested to a sufficient degree, in order for the customer to be sure that the clusters matches the stringent requirements present in the heavy vehicle industry. Stoneridge is aware of the drawbacks of not planning the tests up ahead since there are large costs associated with the number of test performed. The validation plan gets more complex when there are more variants with different functions spread over them. Increased documentation due to larger amount of tests and to keep track that the functions needed to be tested has been tested.

Lower levels of robustness from variants in SMD due to the fact that tests are carried out on functions and not on variants meaning that not all variants will be tested according to environmental and or Electromagnetic compatibility, EMC situations.

When the validation plan is designed it requires more cross functional work due to increasing number of variants since the testers needs to know what function that are on what variant and what to test. There might exist a bit of guesswork in the respect that the function should be tested for the variant where it is most likely to be most unstable.

Cost Estimations in Testing

These approximations are crude and are dependent on complexity, planning and product variants. The cost of a prototype after final assembly, which is a finished cluster for testing, is included. So far during the development of Ursula the fact that the different functions are spread out on the different variants have yielded three vibration test runs instead of one, if there had been only one variant. Two of the tests were carried out in Estonia but the test of the bus variant was carried out at Statens Provningsinstitut. The cost of a single test in Estonia and at Statens Provningsinstitut is approximated.

The tests are carried out at Statens Provningsinstitut, at the Stoneridge branch in Estonia or at the Stoneridge branch in Bromma. The costs of the tests differ between these different possible locations. Increased number of variants and that function are spread out on different variants increases the risk of the need to perform tests at a higher cost at Statens Provningsinstitut due to planning.

The electrical tests have been carried out on two cards with an approximate cost for three testers times three weeks at a internal costing per hour. Here each test has a unique setup but the cost would probably been lowered by approximately one third if there had existed only one variant in the product family Ursula.

EMC tests costs are dependent on how the functions are spread out among the different variants at the SMD stage. This has tripled the cost for EMC tests compared to if there had been only one variant present in the Ursula product family.

The climate tests are dependent on the variants as well these have yielded in doubled test cost compared to if only one variant had been present. There are other tests performed in order to validate the products still the cost of these has not been found to be dependent on the number of variants at the SMD stage. Such tests are life length, mechanical, and IP-tests.

4.3 Industrialization

The primary scope for the Industrialization unit is to prepare the product for production initially and when major changes is implemented on the product that affect the production or when new clusters are phased in to production.

Qualitative Aspects

Since the low volume variants will be produced very seldom during a year the vision test will not generate enough statistical data to develop the optical screening programs to a desired level over time. Therefore the programs get sluggish and inferior for the variants with a low volume since these are not being perfected continuously as much as the ones with a large volume. This behaviour is also apparent for the optimization of production processes. When small batches are running in the line the process will take longer to perfect.

Cost Estimations

Sync-meetings, is the cost per year of meetings needed each week to coordinate the efforts of industrialization due to the number of variants in SMD. These meetings have been active for four years and will last for at least two years more. The cost for Industrialization of the In Circuit Test, ICT due to the number of variants of Ursula in SMD and this is a once in a product lifetime cost. The cost to enable a variant of Ursula IC in the SMD line-software is assessed.

4.4 Production

Between heading 4.4.1 and 4.4.9, production activities together with qualitative aspects are presented. The description is based on interviews, observations and documents. The qualitative aspects are gathered from interviews conducted with persons active within the production at Stoneridge Electronics in Örebro. This is followed by production related cost calculations under heading 4.4.10. A picture showing the factory layout is presented below and is followed by a picture showing the production processes.

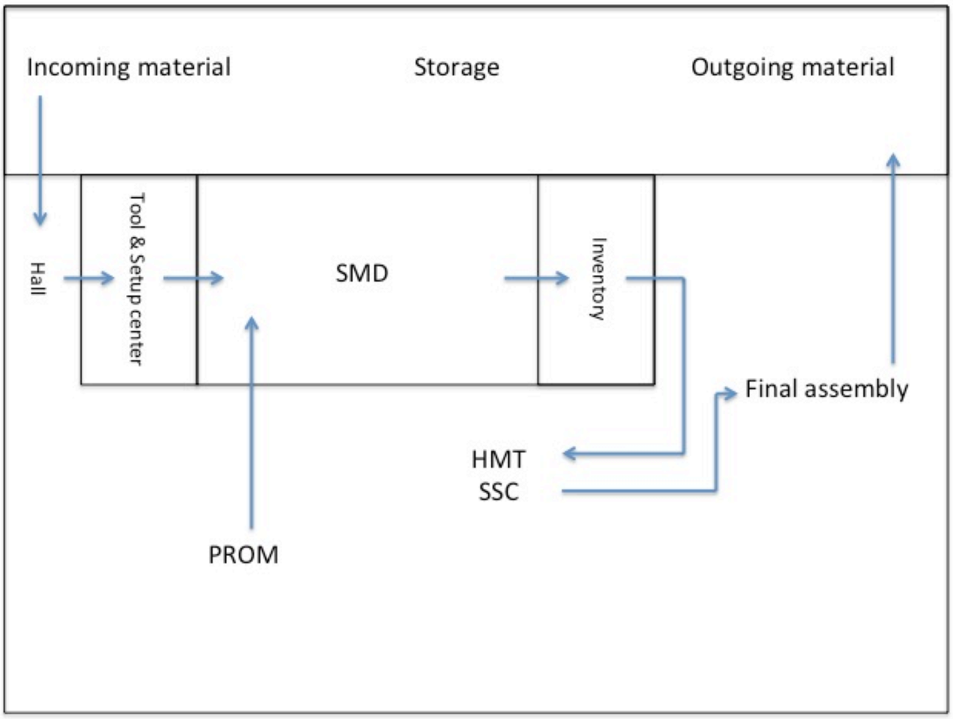

Figure 6 Factory layout

Figure 6 Factory layout, displays the factory layout at the plant in Örebro, the arrows shows a simplified production flow for Ursula IC.

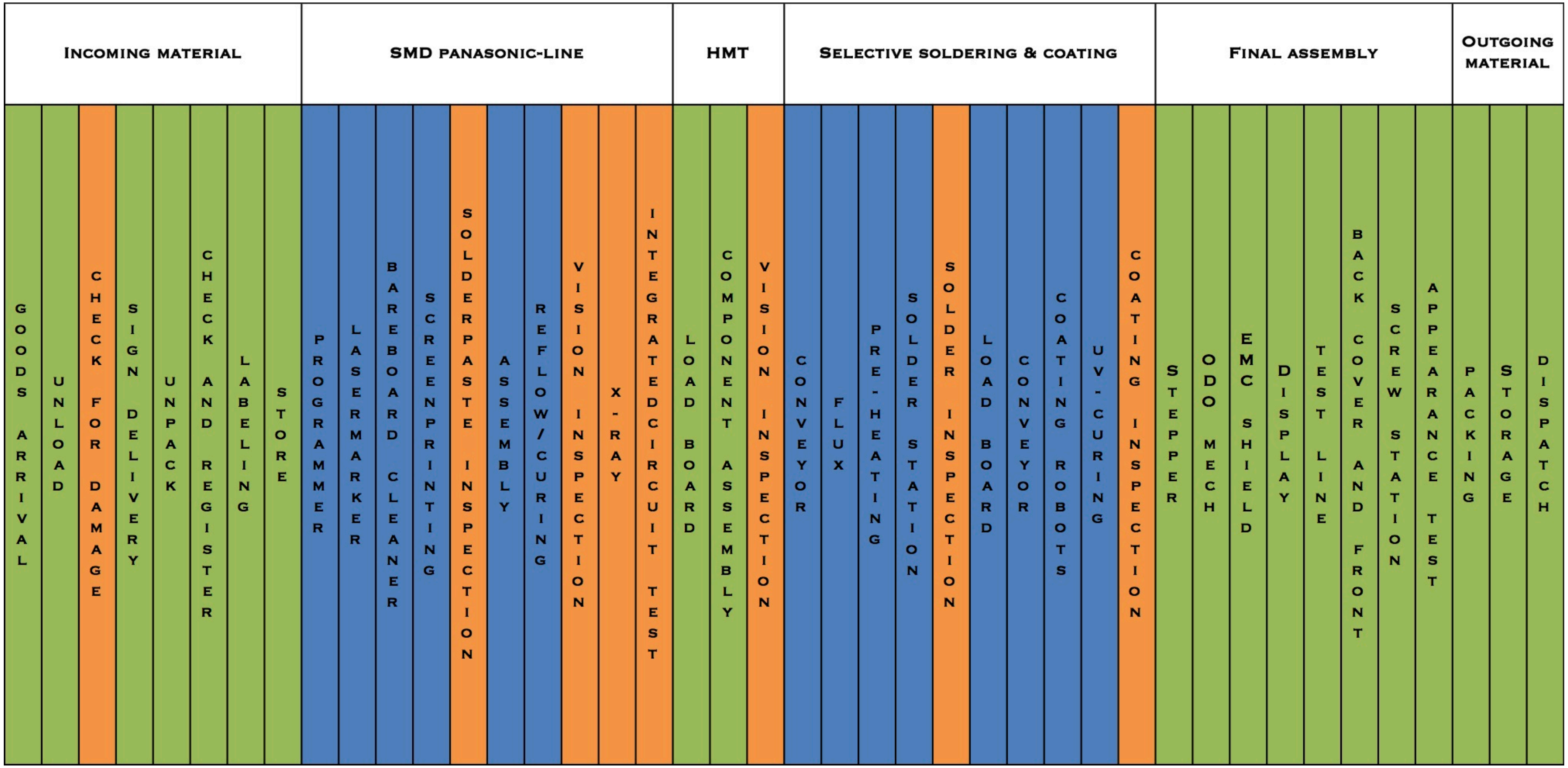

Figure 7 Process flow for Ursula IC in Örebro

In Figure 7 Process flow for Ursula IC in Örebro is displayed, from incoming material to outgoing material. The activities in Örebro is based on process flow for Ursula IC the different colours translates, Blue Automated Operation, Orange Test, Green Manual Operation.

4.4.1 Storage

In the production plant in Örebro the flow starts with incoming goods, there is a storage area primarily for the components used in the final assembly and finished goods waiting for delivery. This storage will be rebuilt as a supermarket as a step in the lean transformation Stoneridge Electronics performs. The PCB cards are stored in a hall between the incoming goods and the Tool and set-up centre, the cards is placed in racks with the approximate dimensions 30 x 35 x 60 cm and have 25 places. The racks are used when handling and storing the cards between the different processes in the factory. Components that are mounted in the SMD line is placed in the Tool and set-up centre, which is located between the incoming goods and the SMD lines. The SMD components are delivered on rolls, some of which are stored on shelves and some in a paternoster-storage and the subcontractor that supplies them owns these components. In the tool and set-up centre there is also a service area and a storage for stencils used when applying paste on the PCB card in the beginning of the SMD line.

4.4.2 Tool and Set-up Centre

In the Tool and set-up centre, trollies are unloaded and loaded with component rolls. The trollies are mounted in the SMD lines and are changed during a product family set-up. The tool and set-up centre is a result from SMED, single minute exchange of dye where the external activities such as changing component rolls is made before the actual set-up in the SMD line takes place. The time to unload and load one trolley is assessed, and the SMD Panasonic line has 8 trollies that need to be adjusted.

4.4.3 SMD

In the SMD line area there are three SMD lines, two, ICT, In-Circuit Testers, re-work area, ICT fixture storage and storage for faulty PCB cards. Ursula IC is run in the Panasonic line. This line is led-free and is shared with one other product family. Ursula IC is not yet ran in full production, it is for now in a ramp-up phase and will go in full production from year 2014 and will then mainly occupy the line.

The Panasonic SMD line consists of six automated operations and four inspection operations, which is also automated this can be seen in Figure 7 Process flow for Ursula IC in Örebro. The line balance itself after the slowest operation. The first operation, which is actually an operation carried out outside the SMD line and is called programmer. Here a ROM, Read Only Memory is programmed, the memory will then be mounted in the SMD line. Next operation in the SMD line is laser marker, a PCB card is inserted in to the line and then the laser marks the card with a serial number, which maps with a database. The card is then flipped and marked on the other side. Then the third operation is a cleaning machine, which cleans the card from dust caused by the laser, this is done with a tool that can be compared with a sticky paper.

After the cleaning of the card it will be printed with solder paste through a stencil in the operation screen-printing. The stencil is the same for all variants of Ursula IC, but there is one for product cluster one and another for cluster two. Next operation is solder and paste inspection, which checks that the solder paste is spread correctly. This is followed by pick and place, in these stations the components are mounted on the board. At this station the change of components or trollies takes place when it is time for product or variant set-ups.

The operation after assembly is reflow/curing, this operation consists of an oven with heating and cooling zones. This is followed by a vision inspection. The vision inspection needs a special program for each variant, at set-ups a list file must be changed. Next step is that follow is that the card will flip around and travel in a conveyor back to screen-printing in order to print the other side of the card. This follows the same procedure as for side one of the card, from operation screen-printing to vision inspection.

This is followed by an X-ray inspection, this is carried out on about 1 board per rack and finally the last operation is the ICT, which tests the boards. The ICT requires a fixture, which is stored near by the machine. The fixture is the same for all variants in a product family. If any of the inspections detects a fault on a board, the board may be re-worked. In order to be sure that the goods are finished at right time if a card gets any defects some extra cards at each batch will be generated out from the SMD line.

The different variants´ PCB cards physically look very alike each other to the human eye, it is hard to see the difference between the cards and this may lead to mistakes by selecting the wrong card. Still each card has a laser marked serial number and each rack has an information note telling the operator what product family and variant it contains.

4.4.4 Variant Set-up

As mentioned, the trollies at the SMD line are only changed when set-ups is made between two product families. If there is place on the trollies to have all the components for all the variants, the trollies will be loaded with them. This is the case for Ursula IC and it do not effect the cycle time to any considerable degree, otherwise the component rolls needs to be changed on the trollies during the set-ups. When it is time for a variant set-up for Ursula IC an operator will attend to that the laser gets a new instruction with a new code, the vision test gets another software and change of instruction how the components will be mounted. During each variant set-up the line needs to be emptied on both sides and after the variant set-up it will be loaded again. The total variant set-up time is approximated according to section 3.5.1.

4.4.5 HMT to Dispatch

After the SMD line the cards will be processed at HMT, hole mounting, where bigger components like batteries and connectors are mounted manually and inspected. The HMT is directly connected to the selective soldering common line and selective coating. At the selective soldering the boards are sprayed with flux, pre-heated to right temperature and components are soldered and ends with an inspection of the soldering. The selective coating processes coats the cards and cure them with UV-light and is then inspected. At the HMT the operators set the sequence of the variants for the final assembly.

The final assembly consists of several stations, both automated and manual. The first station assembles stepper motors, which is followed by assembly of reflectors, EMC shields, displays, overlays and pointers. Next is a test and calibration line followed by assembly of back cover and front, a screw station, appearance test, protection film assembly, labelling, packing and finally dispatch. Components for final assembly drives today a big storage, even though Ursula IC is not in full production the storage for this components is larger than the storage for the other instrument clusters produced in the factory. The pallets used after the final assembly have room for 48 finished products that can be shipped to the customer.

Maintaining item numbers consumes resources, every variant at final assembly have an own item number. Since this is coupled to the variants at final assembly and not completely to the variants at SMD level this will not be considered as a cost driver for the variants in SMD.

4.4.6 Production Planning

The customer order frequency differs in time regarding how often the orders are placed. The planning based on customer orders is carried out on a two months forward basis. A production planner plans the production on a daily basis.

The time and effort spent on production planning is expected to increase due to the number of variants, if the present approach shall be kept where the planner must try to estimate the customer need and build with a safety stock.

4.4.7 WIP

All the cards that are being processed or waiting for continued production are work in process, WIP and bounds capital. The WIP that is coupled to the variants of Ursula IC and thus needs to be considered is the WIP between the SMD line and HMT. The WIP for high volume variants may not be regarded as a major problem since these are likely to have a higher degree of turnover. But for low volumes it might become a problem for two reasons: The first is if to many cards is produced, since there is a risk for rework on the SMD operations conducted on the cards, the production planner often chose to produce some extra cards to compensate for this rework risk. Since the customer is responsible and pays for normal freight, it gets expensive if Stoneridge do not make their deadlines. Since they are forced to use express transportation, in worst case if they do not deliver in time penalties will be induced. The second reason is if the low volume variants are produced seldom over a year but in bigger batches, they need to be stored until the customer wants them.

4.4.8 Revision Changes

When revision changes occur engineers are subject to manual administration work this is time consuming and non-value adding activities therefor it can be considered as waste.

Modification of the vision test software due to Revision changes is dependent on the number of variants. Each variant consumes extra time and the tests must be administered and this is dependent on the number of variants and each variant drives extra time.

Since revision changes is occurring with a frequency of approximately two times per year there is a risk for scrapping. For high volume variants with high turnover corresponds to a low degree of scraping the revision changes will go smooth so long the factory receives heads up. But the cards of the low volume variants may lie around for a long time, which may result in a higher degree of scraping.

4.4.9 Scrap in the Repair loop at the SMD level

There is a repair loop which is a flow for the products that are faulty this is a separate flow where the work are to a large content manual. Operators diagnose what the problem is with the specific card and fixes it. The stockpiling of unfinished goods can build up here since there is not a first in first out prioritization in the repair loop. Therefor variants that are produced seldom can get stuck in this flow. This may result in scraping of low volume variant cards when there is a revision change since these have been lying around for a while and require rework.

4.4.10 Results from Production related Calculations

In this section results from production related calculations is displayed.

Variant Set-ups

From the calculations carried out it can be derived that the costs for variant set-ups per year for Ursula IC differs among variants, according to their run- and volume characteristics. It has been revealed that the variant set-up cost for one of the high volume variants, 5, drives low costs per card. Although for the other high volume variant, 7, the cost for the variant set-up is zero. Because it is the highest volume variant and that this variant would have been present if there had been only one variant of Ursula IC. For the medium volume variants the variant set-ups drive higher costs than for the high volume variants. For the low volume variants the variant set-ups drive costs considerably higher than for the medium and high volume variants. These patterns are seen in the three time scenarios A, B and C. With lowered variant set-up times, the costs are lower corresponding to the different set-up times in each scenario.

WIP

The WIP for the variants of Ursula IC is assessed and the variants have different meantime in the WIP, corresponding to the different run frequency of the variants. The high volume variants have the same average meantime in the WIP. The medium volume variants have quite similar meantime in the WIP and this time is higher than for the high volume variants. For the low volume variants the meantime in the WIP is significantly higher compared to the high and medium volume variants. This has been studied with the assumption of the Saw tooth model for the WIP. The mean value of the WIP for each variant follows the volume of each variant. The capital cost of the WIP varies with the volume of each variant and the mean time in WIP for each variant. The capital cost within the WIP per card, is higher for the low volume variants than for the medium and high volume variants. Each variant drives a surface cost in the WIP since each different variant has to be placed in a separate rack. This is uniform for all the variants except variant 7, for which it is considered to be zero, since this variant would still have been present if there had been only one variant.

Aggregated costs of variants

Aggregated variant dependent costs in production have been calculated including set-up costs, surface cost of WIP and administration costs due to revision changes. The aggregated costs show that the low volume variants drive costs per card remarkably higher than the medium and high volume variants. Still the medium volume variants drive costs that are notably higher than the high volume variants. And the costs for the different scenarios A, B, and C are proportionally according to the different variant set-up times in these scenarios.

Due to scrap in the repair loop and the assumption that all cards of the low volume variants entering the repair loop would be scrapped due to revision changes, a cost may arise, which have been evaluated. This is based on crude approximations and it is hard to predict how the repair loop will look like when Ursula IC is in full production. Therefor this estimation is put outside the other calculations for the production phase.

4.5 Aftermarket

Stoneridge Electronics supplies the aftermarket with spare parts. The customer owns the aftermarket phase for Ursula IC. Usually an instrument cluster produced by Stoneridge Electronics has a market window on six to seven years. After last time buy Stoneridge Electronics must be able to deliver spare parts for 15 years, however this depends on the obligations to the customer and can vary.

In the beginning of a new launch of a product cluster there is usually a higher demand of spare parts than in the end of the product life cycle. But it concerns relatively low volumes, in the magnitude of hundred units per year. There are two alternatives in order to supply units for the aftermarket; produce to stock or build to order, the first binds capital and the latter demands storage of fixtures and stencils if it is not possible to replace a spare part with another upgraded unit.

Components that are discontinued by subcontractors may require a final purchase to build up a storage stock that will last for the entire projected aftermarket need. Another approach to this problem is redesign if the actual component binds a lot of capital or if the volumes are high enough. Depending on how the contracts with the customer looks like it might even be the case that the customer buys a aftermarket stock of components that can be physically located at the Stoneridge production plant in Örebro.

The projected number of units to be delivered during the aftermarket phase may be as low as a hundred per 100000 units produced during the on the market phase. This is due to a generally low breakdown frequency in the industry and the short timespan the trucks spend as economical in the western world, this makes it only worth to repair the trucks instrumentation cluster during the approximately first five years on the aftermarket or something similar since the first trucks has an very high age by this time and these are the one that are likely to brake down by this time. The costs due to variants during the aftermarket phase can be regarded as having a low impact and are therefor not further investigated.

4.6 Concluding Remarks on Present State

The primary quantifiable cost drivers affected by the number of variants is found within production. These are identified to be the variant set-ups in the SMD line and the WIP after the same. The administration of the different variants is according to some of the persons interviewed argued to be a major cost driver. However, estimations have been done, showing that the administration costs that are dependant on the variants at the SMD level are not of great magnitude. Still it is possible that not all administration activities have been found and investigated. Also, the cost for the WIP is not large enough to affect the results of the study as a whole to a large extent. The behaviour of the aftermarket and Ursula's current place in its lifecycle makes it hard to quantify any sizeable variant dependent cost drivers during the aftermarket phase.

There are multiple qualitative problems associated with the variants at the SMD level in the different life cycle phases, these are of different levels of severity. Some of the problems have already appeared, while others are anticipated to do so. Also important to note is that Stoneridge Electronics is operating according to lean production, they have a strong quality focus and the importance of different forms of flexibility is stressed.

5 Benchmarking

Benchmarking has been conducted as a mean to gain inspiration to the development of ideas for a future state. The results of the benchmarking at Ericsson and Scania are presented here.

5.1 Ericsson

Ericsson manufactures among other products Mini LINK ™ at their plant in Borås. The factory has four SMD lines, which has different focus when it comes to what kind of products that goes through each line. The two newest lines from Siemens are identical so which makes it easy to switch between the two SMD lines if something is malfunctioning or if a product need to go at a high volume they can run the product simultaneous in the two lines with ease.

Family setups have been implemented at the SMD stage in production where the setup times between variants in the same family is no existing. In fact they can run different variants within the same product family in different stations in their SMD line. This minimize the downtime when the line is non productive. Ericsson points out that this routing of the control programs for the pick and place machines in the line are carried out automatically using a central line computer. The family setups are carried out using table setups so that Ericsson never or very seldom change the feeders present in each table, this have been a focus area from Ericson's side both because they mean that the stripes on which the components are fitted on can be located pitched in the feeder and the line will automatically adjust to this deviation automatically from previous pickings from the actual feeder. If then the feeder is swapped out for a different one where the stripes is pithed towards the other side of the feeder the deviation when the picker picks up the component will deviate with both the lines adjustments to the previous feeder and the deviation. It also implies wear and tear on the feeders to swap them compared to splicing and carry out table setups.

However these family setups present affect the cycle times negatively since the line is automatically balanced but according to the slowest process for the variant present in the line that needs the most work. Therefor they use software from Siemens that sets the sequence that is optimized from different parameters that affect the production efficiency. Still Ericsson means that they save up on minimizing the downtime and gets around other problems using family setups compared to not use family setups and optimize based on cycle times.

The SMD lines have a pull system when it comes to what to build from storage of SMD boards after the SMD line where the demand for SMD Boards is created. Using this storage as a safety stock or buffer help level out the demand for SMD boards at the production plant so that the family setups when tables are swapped does not need to be carried out as often.

Ericsson produces Mini LINK ™ at the SMD stage with a modular approach so that on a PCB at Ericsson there is more than one SMD module on each PCB that are separate in-line using a milling cutter. This approach with physical modules gives the possibility to delay the differentiation for their base stations until the assembly stage. This gives the possibility to create a lot of final variants using few variants at the SMD stage. For example each Mini LINK ™ consist of two different SMD PCBs, one control board that are produced in three variants and one mainboard that is produced in 30 variants. The software is then uploaded to the base station and using this software to enable and disable different functions in the hardware, which creates up to thousand variants out to the customers. These thousand variants do not necessary have large differences among each other.

5.2 Scania

The interview with an employee at Scania gave some interesting thoughts about product variants. Scania is well known for their module system that provides great flexibility, which has become very successful in order to cope with many variants and to be able to mass customize. The interfaces are standardized and must be able to function with different weight classes, for example that different engines still have the same attachments. Scania tries to reuse platforms and standardized components between different products, this saves money for example through easier maintenance. Scania tried as far as it was possible of letting one function correspond to one unit and not connect several functions or build in connections. The electronic system architecture is the same in all trucks and busses for all markets. Sometimes ad on functions are shipped with the vehicle but is disabled by software, this can however be enabled at a later stage.

6 Suggestions for a Future State

Based on the results from Present State a Future State is developed. The approaches' under future state can be sorted into two categories, the first, which reduces the variants, the second which handles the variants.

6.1 Reduce Variants

In order to decrease the cost impact and the qualitative problems identified in the present state an approach towards reduction of variants at the SMD stage is evaluated. This is done through merging variants, so that all functions are kept and no changes are to be seen by the final customer. For starters mergers of TCO and TSU variants were regarded since these cards has the same functionality except the tachograph simulation unit that is present on the TSU variants.

In order to reduce variants further, variants with similar function structure were considered for mergers. These scenarios were evaluated according to what savings they would imply on a yearly basis but no costs for making the changes were regarded.

Table 2 displays how many per cent of the variant set-ups that must be saved by mergers of different variants, in order for the mergers to be economically feasible. This table is valid for scenario C, today's set-up time and the projected production volumes of 2017.

Merger of	Required reduction of set-ups
1&2	0%
3&4	14%
5&6	26%
7&8	50%
10&11	5%
1&2&10&11	10%
1&2&9&10&	19%

Table 2 Required reduction of set-ups

The economical feasibility for the different mergers related to the cost of WIP, revision changes, extra material and set-ups are displayed in Table 3 Variant mergers feasibility. It shows, that for scenario C, all the mergers except the TCO/TSU merger of variant 7&8 would be saving money, compared to the current variant line-up for Ursula in the SMD stage of the production. For scenario B, all the mergers except the mergers of variants 5&6 and 7&8 would save money on a yearly basis. In scenario A, all mergers except the mergers of the variants 3&4, 5&6 and 7&8 are saving money.

Variant mergers	1&2&10&11	1&2&9&10&11	1&2	3&4	5&6	7&8	10&11
Scenario A, Economical feasibility	Feasible	Not feasible	Feasible	Not feasible	Not feasible	Not feasible	Feasible
Scenario B, Economical feasibility	Feasible	Feasible	Feasible	Not feasible	Not feasible	Not feasible	Feasible
Scenario C, Economical feasibility	Feasible	Feasible	Feasible	Feasible	Feasible	Not feasible	Feasible

Table 3 Variant mergers feasibility

The following scenarios were validated regarding technical feasibility, this showed that the TCO/TSU mergers were possible. At the stage after SMD, HMT these variants are needed.

The merger of variant 1&2&10&11 is possible at the SMD level but at the HMT level the boards' needs to be different since an internal speaker is mounted. And this is a difference between the variants. The merger of variant 1&2&9&10&11 is not possible with the current product structure since the warning lamps have different colours on the variants 1&2&10&11, though in theory this might be possible to work around.

The mergers that are economical and technically feasible can be combined resulting in six variants, if there is no work around the fact that the variant 9, bus, has different colours of the warning lights compared to the other low volume variants, but if there were a possible work around the result would be five variants. This is based on the costs given that the setup times are as high as scenario C. The result of reducing the variants shows that it is economically feasible in several of the scenarios even though the set-up times is decreased. However, in order to increase the flexibility in the SMD line strives for decreased set-up times can be something to consider. The number of resulting variants of Ursula IC at the SMD stage is presented in Figure 8 .

Scenario	Merger of variants	Number of variants left
A	1&2&10&11	8
B	1&2&10&11	8
C	1&2&10&11, 3&4, 5&6	6

Figure 8 Number of variants left for different scenarios

6.2 Manage Variants

Inspired from one of the companies from the benchmarking a strive towards shorter set-up times is suggested. Ericson managed to have short variant Set-up times by not emptying the line between their variant set-ups. Also by having so called family, part and loaded set-ups which maximum took a few minutes and by having a central unit for automatically changing the software and thereby having less downtime. Stoneridge already plan their variant set-ups after common components when the trollies are loaded and also have a central unit that sends the new software. With a bar code scanner it perhaps will not be necessary to empty the line. Decreased set-up times have many advantages and this is something that other companies are able to maintain through their production.

In order to support the administration activities a PLM system can be implemented. Which could facilitate planning of different hardware tests and decrease the work concerning administration of variants. This is already something Stoneridge Electronics has in mind and will implement.

Mix-ups between cards of different variant might occur this could be avoided by marking up different variant more comprehensible and clear. A colour coding could be a way to solve this or something that is more dazzling than just a number, barcodes could be introduces and scanned after the SMD line. This is a problem not just in production but also at the development stage since developers might not be able to keep all de different variants in mind, which can reduce their ability to connect to the product and thereby get distanced from the product.

7 Discussion

The discussion is divided in three parts, method and methodology, present state and future state.

7.1 Method and Methodology

The literature by Zhang and Tseng supported that a qualitative study of where costs due to variety occur might be needed. At start the number of cost drivers found to address the costs associated with the variants present were believed to be higher. This since the nature of the variants present where costs arise due to the functions present on different variants rather than the different physical variants. Since the functions would have all been necessary even if only one physical variant had existed for the Ursula product family. Some of the variety cost drivers that were expected to be found, were not present, such as cost of fixtures and stencils in the SMD, while cost drivers of different nature appeared such as administration costs at different stages of the value chain. Early in the project variety induced administration costs were considered to bay outside the boundaries of the project. Since these were considered not to have a large impact on the result and to be hard to capture. However during the span of the project a strive to cover the administration costs were added.

Interviews conducted with different persons at Stoneridge gave a good mean to obtain both qualitative and quantitative data. The interviews were often of a semi-structured nature, which gave both structure while allowing room for discussion and collection of data that was not always expected before the interviews. Much of the data used is collected from interviews, there is always a risk that the answers may be based on opinions that reflects the feeling of something. But according to Zhang and Tseng it is more important to get an estimation of the magnitude of the cost driver rather than exact numbers, this study relies on this statement. When quantitative data is gathered by using interviews there is a risk that data can be distorted. However the persons that have been interviewed is the ones that know the processes best and therefor the data can be considered to be valid enough. The meetings with our supervisors during the project helped to validate the data collected and ensure that the results lay within what they thought reasonable. These meetings were also a source for a different perspective on the different parts of the project as it evolved.

Questionnaires could have caught some of the effort spent on administration coupled to the variants. However due to time constraints and uncertainty concerning the usability of the result from such a study conducted during a such short time would have affected the outcome of the project in major way was doubtable. Therefor the idea with a questionnaire study was dismissed but if such a study had implemented at the start of the project it would have had a higher potential. Such a study would probably have strengthened the argument to reduce the number of variants for Ursula at the SMD-level.

The generic variant, which is the one with the highest volume stands for zero set-ups due to that one variant must exist, the other variants with high volume stands for one set-up each and the middle an low volume variants stands for two set-ups each, which means that both the change over to and from the variant is counted. However, it is possible that depending on how often the different variants are produced the number of set-ups the different variants stands for may be incorrect and thus have an impact on the results of the calculations. But since the number of set-ups the different variants stands for can be incorrect both up and downwards, it was decided that the alternative used in the calculations was the best trade-off.

Concerning the administration costs within the development it has been some problems with collecting the data and concerning the scrap which is based on units in the re work loop after SMD it was the best way for the moment to base the estimations on and get a hint of the magnitude. The estimations of these two cost drivers could have been included in the production calculations in section 4.4.10 this is not done since the crude nature of the estimations. The WIP after the SMD line is calculated by an approximation with the saw tooth model as described in the literature chapter. This was discussed with two employees within the logistics and production management, whom thought it was a good model to use.

The model for the calculations is not validated therefor there is a risk for errors that have been discovered during the project process and can have impacts on the results. However the Excel document with cost calculations is handed over to Stoneridge for them to use and evaluate.

During the project a strive towards that the development of the future state should be more focused on product development. This turned out to be rather hard since the contact with the design and development in Bromma has not been intense enough. This could have given an extra dimension to the project.

7.2 Present State

Stoneridge have flexible production lines in the SMD regarding the products, they can produce a wide range of different SMD cards. However, for Stoneridge to be able to run a just in time production efficiently and be able to level out the flow shorter setup times is a necessity since variants are present. According to Jonsson and Mattsson short set-up times is a necessity when going towards a one-piece flow in a mixed model production. Strives could be to minimize the setup times for the SMD line in which the Ursula product family is produced. Especially the setup times for variant setup since there are many variants present in the Ursula product family to this date and there is a risk that there will be even more variants in the future. Even though it is not likely that the set-up times can be largely reduced in the short run.

Stoneridge Electronics has a production that is able to manage different product families, variants and volumes; the production consists of flexible processes from SMD to final assembly. There are test functions throughout the whole production in order to fool proof since high quality is very important to Stoneridge Electronics. The long set-up times have a negative impact on the flexibility of the SMD line but at the same time it is understandable that there is reluctance towards shorten them in order to not risk the quality since emptying the line provides a quality assurance.

When the product family Ursula IC will go in full production other cost drivers might be identified, this can be argued since it is hard to identify problems in a production line that is not utilized to a degree that is somewhat comparable to the capacity it is intended for. This follow the same arguing as the one present in the concept the Japanese sea which illustrates that when buffer levels and storage levels are lowered the problems will appear above the surface. That would probably have an impact on the results of the calculations and the qualitative problems in the present state. However, it would probably increase the willingness for reducing the variants since it would yield additional costs and qualitative problems.

The WIP for the product family Ursula might work like a veil that hides problems that would be exposed if the WIP levels were lowered this can be compared to the issues described by the concept of the Japanese sea. The WIP levels may swell further both due to full production and due to the increase of the number of variants that will be apparent when the next cluster is phased in.

With the new situation associated with the many variants of Ursula IC on the different production levels, it is the general feeling among the employees that there exist worries for problems that perhaps will not appear. Maybe such a worry is caused by the new situation itself that there is something new that must be managed and a bit of uncertainty lies within.

Regarding development test and industrialization costs, which several of them is occurring once in the beginning of the product lifecycle it is perhaps not much relevancy or possibility to act towards them now, since these can be regarded as sunk costs. But in the future this is something to consider by having less variants at the SMD level and thus save some costs.

7.3 Future State

The ideas of the future state have several advantages to the present state. By reducing the number of variants it will decrease the cost drivers and the qualitative problems. Perhaps it is not worth to put an effort within this cluster, but for the next or the final cluster it will be an alternative to consider. Also to have this in mind when developing future instrument clusters, to see the whole picture and not sub optimize certain costs.

With fewer variants early in the production flow the point of differentiation will be moved forward. According to Hu et al., a higher degree of automation and smaller batch sizes is enabled by delayed differentiation. The SMD production line at Stoneridge can be seen as inflexible when it comes to the variant set-up times. This implies that it is preferable to have few variants early in the production flow. Still, MacDuffie, Kannan and Fischer states that not all studies show that product variety leads to higher costs in production. Nevertheless this must depend on how the production system is designed and the product architecture.

The visit at Ericsson showed a different approach to the product structure where the cards in the SMD line contained different modules that were separated using an inline mill cutter. Then later in the production these cards where combined into the final product. This gave Ericsson the possibility to create a range of different final variants late in the production flow by keeping a smaller number of variants in their SMD line. This could be applicable at Stoneridge for different products. Perhaps could the functions that differ between variants be located on different physical modules. Then the common functions and corresponding components could be a physical platform. In this way Stoneridge should be able to keep the number of variants down early in production while still maintaining a lot of variants out to the customer. Modularity according to Slack and Lewis enables mass customization while keeping cost down. However modularity brings drawbacks that need to be addressed such as interfaces that can be costly and decrease reliability.

The Ursula product structure can be seen as modular since all the variants are created from a master schedule that contain all functionality. The design engineer selects what functions to go with in each variant but these are mounted on the PCB board early in production. The physical modules could be assembled later in production and thereby the point of differentiation could be moved until final assembly. More frequently demanded standard modules could be kept as storage as a safety stock to ensure a smooth production while more rare modules could be built to order.

New clusters will see production and these will be alive in the production simultaneously at least during overbridging faces between clusters. The new clusters will thereby create more variants present in production at the same time. This has the potential to amplify the qualitative problems such as the risk of mix-ups between variants.

There are also some risks that need to be considered due to the ideas of the future state. There will be more components on each card, can this affect the robustness of the card even though the components are not in use and disabled? More components on each card may also require a larger component stock. It demands an enhanced cooperation between different divisions and functions within the company, for the entire organization to see a larger picture. The costs for merging variants are not investigated and is should be done before a decision of when and to which degree the variants will be merged. Such costs may be driven from new soft wares to the product itself and inspection programmes, prototype test runs, development tests and administration activities.

During the study interviewees have mentioned problems related to the variants at final assembly frequently. At the final assembly there exists many variants, which drives costs such as storage. However, since these variants are derived from customer demands there is nothing that Stoneridge can do in order to reduce them unless they do not change their relation to their customer. A PLM system could help Stoneridge manage the variants by handling product and production information throughout the entire lifecycle.

Reduce variants imply more material shipped on each product which can be regarded as a step backwards when it comes to resource use and ecological sustainability. While at the same time it is more sustainable from an economical and social point of view. Since it could enable a higher profitability for the company making the employment more secure for individuals.

7.4 Recommendations

The recommendation for Stoneridge is based on the suggestions for a future state. In order to reduce the impacts of the cost drivers merging variants at the SMD stage is a solution that not only has the potential of cutting cost but also on reducing qualitative problems associated with the number of variants. Therefor a recommendation for Stoneridge is to consider the ideas for future state and in particular a merger of some of the variants while reflecting upon the risks and costs associated with it.

The largest variant dependent cost driver identified in the study is the Set-ups in the SMD line. Decreasing the time consumed by set-ups comes with multiple positive effects such as increased flexibility and responsiveness of the production process. Thus enables for example increased possibilities to level out the flow. Despite this economic incentive to reduce set-up times the qualitative problems will remain. Stoneridge already have plans on implementing a PLM solution, this has the potential to facilitate some of the problems associated with the variants and is therefor something to consider.

The possibilities coupled to increased focus on physical modularity can be investigated further. In order to reduce the complexity due to product variety revealed in production, while maintaining product variety demanded by the customer. The product architecture can be reviewed keeping aspects from all phases in the lifecycle in mind. A similar thought is when planning and developing new products, that optimization should be based on the whole value flow.

8 Conclusion

In the present state, the largest variant dependent cost driver in this project have been identified in production as the set-ups in the SMD line, since it is costly to stop the line. There are also different types of administration activities, WIP, scrap and material that act as variant dependent cost drivers. The variants drive costs during the development and industrialization phases as well, some of these costs has the behaviour that they occur once in a product lifecycle. There are several qualitative problems coupled to the variants of Ursula IC at the SMD level in the different phases of the lifecycle. These are of various characters and have different implications.

The product architecture affects the complexity within production, products subject to mass customization can benefit from a modular product architecture and delayed differentiation. Suggestions for future state, which contributes to keep the lifecycle costs down for Ursula IC, were developed. Merging of variants at the SMD level is one idea for a future state, that have the potential to reduce the impact of both qualitative and quantitative problems identified in the study. By merging variants, the number of resulting variants at the SMD level with the set-up time of today could be reduced to six, still being feasible. Some of the costs during the industrialization and development could have been avoided if fewer variants would have been present. Another idea of the future state is to manage the variants, this require shorter variant set-up times and a system supporting administration activities. If the variants are managed, the costs driven by the variants are reduced and the negative economic impact of mass customization is decreased. Still this does not take away all the qualitative problems. This shows that there are factors of both qualitative and quantitative nature to address when a company is subject to mass customization.

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11 Appendices

Exhibit 1 Simplified calculation sheet for present state

Gröna fält är de som ska varieras

Variant	1	2	3	4	5	6	7	8	9	10	11
Volym	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Antal körningar per vecka	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Antal betalda setuper per år	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Antal körningar per år	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Betalfaktor	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Variant set-up kostnad	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Materialkostnad per kort SMD	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Batchstorlek	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Veckor mellan körningar	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Ögonblicksgenomsnitt WIP	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Genomsnittlig liggtid dagar	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Genomsnittligt värde WIP	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Kapitalkostnad/år WIP	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Summa	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Summa per kort	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX

Antal produktionsveckor	XXX
Direkt Maskinkostnad	XXX
Operatörkostnad/timme	XXX
Fixed OH	XXX
Summa Linekostnad/timme	XXX
Ränta WIP	XXX
Effektiv stopptid variantsetup	XXX
Kostnad vid revision per år och variant	XXX
Ytkostnad WIP per år och variant	XXX

De gröna fälten i den stora rutan är tänkta att varieras beroende på om volym, antal körningar per vecka, eller betalfaktor ändras.
De blå fälten visar vilket utfall som fås, i detta ark är endast kostnader för produktion med.
Betalfaktor innebär hur många variantsetuper en variant står för vid en körning.
Den lilla rutan innehåller data som också kan varieras efter behov.
Effektiv stopptid variantset-up, innebär den ekvivalenta tid linen står stilla omräknat på grund av ramp up och ramp ner faserna. XXX min motsvarar de XXX min en variantsetup tar idag.
Kostnad vid revision per år och variant innebär den kostnad som hittats. Denna kostnad är för två revisionsändringar per år.

På nästa ark, sammanslagningar, visas det beräknade resultatet av variant sammanslagning.

Exhibit 2 Simplified calculation sheet for variant mergers

Ihopslagning av varianter

Gröna fält är de som ska varieras

Sammanslagningar	1&2	3&4	5&6	7&8	10&11			1&2&10&11	1&2&9&10&11
Volym	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Antal körningar per vecka	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Antal betalda setuper per år	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Antal körningar per år	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Betalfaktor	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Variant set-up kostnad	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Materialkostnad per kort SMD	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Batchstorlek	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Veckor mellan körningar	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Ögonblicksgenomsnitt WIP	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Genomsnittlig liggtid dagar	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Genomsnittligt värde WIP	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Kapitalkostnad/år WIP	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Summa	XXX	XXX	XXX	XXX	XXX			XXX	XXX
							Variant	Extra materialkostnad per kort	
Extra materialkostnad per kort	XXX	XXX	XXX	XXX	XXX		1	XXX	XXX
							2	XXX	XXX
							10	XXX	XXX
							11	XXX	XXX
							9		XXX
Extra materialkostnad	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Sparat från att ej köra	XXX	XXX	XXX	XXX	XXX			XXX	XXX
Utfall	XXX	XXX	XXX	XXX	XXX			XXX	XXX

Det blå fältet visar resultatet av sammanslagningar.
Antal körningar per vecka har vi valt att ha samma som för den variant med högst körfrekvens av de som slagits ihop.

Exhibit 3

List of interviewees

This list presents the titles of the persons that have been interviewed, discussed with, or that have provided information necessary for the project.

Personnel at Stoneridge that have contributed mainly with information to the present state and some also with opinions for the development of future state:

Production engineering manager

Industrialization manager

Operators

Production engineers

Production planners

Production technicians

Production manager

Logistics manager

Logisticians

Market manager

Director marketing/sales

Controller

Design engineer

Test engineer

Personnel at Scania and Ericsson that contributed with information during the benchmarking:

Head of diagnostic architecture and tools at Scania

Product technician at Ericsson

Technical manager at Ericsson