CHALMERS
UNIVERSITY OF TECHNOLOGY

# Sourcing model for production tooling

## A case study at Volvo Car Corporation

Master's thesis in Supply Chain Management and Quality & Operations Management

SANDRO SAVARIN

CHI WANG

Department of Technology Management and Economics
*Division of Service Management and Logistics*
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016
Report No E2016:074

REPORT NO. E2016:074

# Sourcing model for production tooling

A case study at Volvo Cars Corporation

SANDRO SAVARIN
CHI WANG

Examiner: Gunnar Stefansson

Department of Technology, Management and Economics
*Division of Service Management and Logistics*
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2016

Sourcing model for production tooling
A case study at Volvo Cars Corporation
SANDRO SAVARIN
CHI WANG



REPORT NO. E2016:074
Department of Technology, Management and Economics
*Division of Service Management and Logistics*
CHALMERS UNIVERSITY OF TECHNOLOGY

SE-412 96 Gothenburg
Sweden
Telephone +46 (0)31-772 1000

Printed by Chalmers Reproservice
Gothenburg, Sweden 2016

# Acknowledgement

This study is a result of the knowledge, insight and feedback given by the employees we have met during our time at Volvo Cars head office in Gothenburg and the supervisors at both Chalmers University and at Volvo Cars. The amount of time, knowledge and passion the interviewees have been willing to share with us has been remarkable. We would like to take the opportunity to thank all of those who have been involved during the project and helped us to execute and accomplish this thesis.

A big thanks to our supervisor at Chalmers, Gunnar Stefansson who has been encouraging and guiding throughout the end to end process of this thesis. A big thanks also to our sponsor at Volvo Cars, Martin Lidén who initiated the ideas that led up to the aim and content of this thesis. A great thanks also goes to our Supervisor Andres Nuudi and Coordinator Malin Gullstrand for backing us up and supporting us on all accounts during this project.

By performing this study at Volvo Cars Direct Purchasing and Program Purchasing department we have gained invaluable insight and deep understanding of the sourcing process within a frontier industry when it comes to purchasing. We have further gained priceless insight in the progressive automotive manufacturer, which for sure we will benefit from for the rest of our careers!

Chi Wang & Sandro Savarin

Chalmers University of Technology
Gothenburg, Sweden
2016-06-01

# Abstract

This is a case study performed at Volvo Cars with the aim to improve decisions regarding production tooling in the sourcing process of car components within the progressively regionalized, global automotive manufacturer. As production tooling is one of the most costly element of a car project, decisions for instance, whether to own single, double or even triple sets of production tooling for a component are critical to handle properly. By analysing the sourcing of five different commodities, this thesis provides knowledge on how to create a revised decision model for production tooling decisions for when components are used for final assembly at more than one region.

The analysis consist of the **three** following **steps**. **Firstly** an analysis of one historical sourcing case from each of the five commodities using with what the authors call the *existing sourcing model* to understand the decision on production tooling setup. The current model when taking single versus multiple production tooling decision is based on a TARR analysis where the investment in new production tooling and potential design and development lump sum at new location(s) are weighted and compared with the savings in landed cost over the car project's life cycle. Since the current landed cost calculation at Volvo Cars does not take in parameters such as tied up capital from lead time and flexibility into consideration, the **second** step of the analysis is to analyse the same historical sourcing case from each of the five commodities with a *revised sourcing model* where the authors include the additional parameters into the landed cost. The additional parameter of tied up capital from lead time is quantified by the work in process multiplied by the weighted average cost of capital, which is 13 % at Volvo Cars. The work in process comes from the famous little's law where work in process equals the lead time multiplied with the average consumption rate in units per time period. The additional parameter of tied up capital from flexibility is taking an materials planning and logistics perspective where flexibility is seen as Volvo Cars ability to consistently fulfilling a fixed service level towards the production flow, in this thesis case a service level of 98,8%. The service level can be translated to a service factor, which is used to statistically determine and generate the appropriate safety stock based on normal distribution to cover for disruptions and variance in demand using gathered data from Volvo Cars in terms of average demands, lead times and its standard deviations for the sourcing cases the authors analyse. The **third and last** step of the analysis consist of a meta-analysis of the first and second step to indicate the delta in landed costs and hence TARR analysis between the *current* and *revised model* to see if this delta will cause changes in the decision on production tooling setup in any of five sourcing cases and present the results.

This study concludes that adding the parameters of tied up capital from lead time and flexibility has a substantial financial effect on the TARR analysis, thus can have an impact on the decisions on number of sets of production tooling even though only one of the five cases in this study showed any difference in production tooling decision when taking the added parameters into consideration.

# Table of content

Acknowledgement ..... iv
Abstract ..... v
Table of content ..... vi
List of Figures ..... x
List of Tables ..... x
List of Abbreviations ..... xi
1. INTRODUCTION ..... 1
1.1 Background ..... 1
1.2 Introduction to the case company ..... 2
1.3 Problem Analysis ..... 4
1.4 Purpose of the thesis ..... 6
1.4.1 Research questions ..... 7
1.5 Scope and delimitation ..... 7
1.6 Expected outcome ..... 8
2. METHODOLOGY ..... 9
2.1 Research Approach ..... 9
2.2 Research Process ..... 10
2.3 Description of methods ..... 11
2.3.1 Literature research ..... 12
2.3.2 Participant observation ..... 12
2.3.3 Unstructured interviews ..... 12
2.3.4 Semi-structured interviews ..... 12
2.3.5 Analysis of data ..... 14
2.3.6 Confidentiality ..... 14
2.4 Ethical considerations ..... 14
2.4.1 Harm to participants ..... 14
2.4.2 Lack of informed consent ..... 15
2.4.3 Invasion of Privacy ..... 15
2.4.4 Deception ..... 16
2.5 Trustworthiness ..... 16
2.5.1 Credibility ..... 16

2.5.2 Transferability ....17
2.5.3 Dependability ....17
2.5.4 Conformability ....17
2.5.5 Reflections on limitations in the research method of case studies ....17
3. THEORETICAL FRAMEWORK ....19
3.1 Purchasing ....19
3.1.1 Primary tasks and responsibilities of purchasing ....20
3.1.2 The purchasing process ....21
3.2 Sourcing Strategies ....24
3.2.1 Single and Sole Sourcing ....25
3.2.2 Multiple and Dual Sourcing ....25
3.2.3 Contingency Sourcing ....25
3.2.4 Parallel Sourcing ....26
3.2.5 Single versus Multiple Sourcing ....26
3.2.6 No sourcing strategy ....29
3.2.7 Sourcing strategy summary ....29
3.3 Buyer–supplier relationships ....30
3.4 Working capital for decision making ....30
3.4.1 Lead time and working capital ....31
3.4.2 Flexibility and working capital ....32
3.5 Landed cost ....34
3.6 Time Adjusted Rate of Return analysis ....36
3.7 Regionalized Supply Chains ....38
3.7.1 Shorter global value chains ....38
3.7.2 Localise to thrive ....38
4. EMPIRICAL DATA ....40
4.1 Volvo Product Development System ....40
4.2 General information on Purchasing Organization ....42
4.3 Purchasing role in VPDS ....42
4.4 Purchasing Process Description ....43
4.4.1 Sourcing Process ....44
4.4.2 Ordering Process ....45
4.4.3 Quality Assurance Process ....46

4.5 The Sourcing Template ....47
Section I, Sourcing plan ....47
Section II, Sourcing Approach....48
Section III, Sourcing Consensus ....48
Section IV, Summary and recommendation ....49
4.6 Production Tooling....50
4.7 The five commodities....51
Commodity 1: Steering Wheel....51
Commodity 2: Seats....52
Commodity 3: Subframes....53
Commodity 4: High voltage batteries....55
Commodity 5: Fuel tanks ....56
4.8 Adding parameters to the current sourcing model....58
4.8.1 Tied up capital driven by lead time ....58
4.8.2 Tied up capital driven by flexibility ....61
5. ANALYSIS ....64
5.1 Production tooling decision analysis ....65
Commodity 1: Steering wheels....66
Commodity 2: Seats....67
Commodity 3: Subframes....67
Commodity 4: High Voltage Batteries....68
Commodity 5: Fuel tanks ....69
5.2 Tooling decision summary ....70
6. DISCUSSION....72
6.1 The impact of the additional parameters....72
6.2 The trustworthiness of WACC....74
6.3 Supplier owned production tooling....75
6.4 Flexibility as end customer service level ....75
7. CONCLUSION ....77
8. FURTHER RESEARCH ....78
8.1 Supplier owned tooling for core commodities....78
8.2 Further investigation on WACC ....78
8.3 Flexibility in terms of end customer service level ....79

9. FINAL CONTEMPLATION .....80
REFERENCES .....81
BOOKS, REPORTS AND DATABASES .....81
WEB LINKS AND PRESENTATIONS .....85
APPENDIX .....86
Appendix 1. Semi-structured Interview questions .....86

# List of Figures

Figure 1.1. Volvo Cars' Top Ten Markets – 2015 (Volvo Cars Corporation, 2016a) ..... 2
Figure 1.2. Volvo Cars global presence and manufacturing footprint in the three regions Americas, EMEA and Asia Pacific (Volvo Cars Corporation, 2016a). ..... 3
Figure 1.3. The connection between the additional parameters and the TARR analysis. ..... 6
Figure 2.1. The research process and the connection to the chapters in the report.....10
Figure 2.2. The seven possible production tooling scenarios to analyse. .....11
Figure 3.1. Adopted from van Weele (2014).....20
Figure 3.2. The processes within the purchasing function (adopted from van Weele, 2014).....21
Figure 3.3. Purchasing process approach and interfaces (adopted from van Weele, 2014) .....22
Figure 3.4. Buyer-supplier dependency (adopted from Blome, 2009). .....28
Figure 3.5. Demand Predictability and Lead time, NG SI LING (2015) .....32
Figure 3.6. Safety stock and requirements in relation to service level (David J, 2009).....34
Figure 3.7. Landed cost illustration.....36
Figure 3.8. Manufacturing footprints: Getting to plant X (adopted from Lee & O'Marah, 2013)..39
Figure 4.1. Volvo Cars Product Development System (Volvo cars Intranet, 2014) .....41
Figure 4.2. The product development cycle (Volvo cars Intranet, 2014) .....42
Figure 4.3. The purchasing process at Volvo Cars (Volvo cars Intranet, 2014) .....43
Figure 4.4. The Sourcing process (Volvo cars Intranet, 2014).....44
Figure 4.5. Picture illustrating a set of production tooling. (HLH prototypes, company website) 50
Figure 4.6. The seats product tree. .....52
Figure 4.7. The subframe variation tree.....54
Figure 4.8. The fuel tank variation tree. .....57
Figure 4.9. Landed cost at Volvo Cars and its constituent parts (Adopted from interview with landed cost specialist at Volvo Cars).....59
Figure 4.10. Components of forecast accuracy (Adopted from the interview with the Value Chain Development Project Manager).....62
Figure 5.1. Analysis framework - example of impact from additional parameters .....65
Figure 6.1. Impact of tied up capital from lead time and flexibility on the landed cost .....73

# List of Tables

Table 1. List of commodities and the rationale behind the choice of them. ..... 7
*Table 2. List of interviewees, date of interview, role of interviewee and interview topic.* .....12
Table 3. Relation between service level and service factor (David F, 2015) .....33
Table 4. Example of TARR analysis (Emmanuel (1998).....37
Table 5. Summary of business cases and impact analysis of additional parameters.....70

# List of Abbreviations

CE - Cost Estimator
CEVT - China Europe Vehicle Technology
CMA - Compact Modular Architecture
CPPA - Commercial Program & Pricing Agreement
D&D - Design & Development
DM&PP - Direct Material & Program Purchasing
ESOW - Engineering Statement of Work
INCOTERMS - International Commercial Terms
JIS - Just in Sequence
JIT - Just in Time
KPI – Key Performance Indicator
MP&L - Material Planning & Logistics
PPAP - Production Part Approval Process
RFI - Request For Information
RFP - Request for Proposal
RFQ – Request for Quotation
SCM - Supplier Choice Meeting
SLA – Service Level Agreement
SOP - Start or production
SPA - Scalable Product Architecture
SQL - Supplier Quality Logistics
SQM - Supplier Quality Management
TARR - Time Adjusted Rate of Return
TCO - Total Cost of Ownership
VPDS - Volvo Product Development System
WIP - Work In Process

# 1. INTRODUCTION

*This chapter starts with describing a background to the study as well as the reasons why the notion is interesting from an academic and a business perspective. The background introduces the reader to the global trends related to the specific research area followed by an introduction to the case company and their specific business area that the purpose of this research will cover. The chapter will further describe the purpose and the problem description leading down to the research questions of that will be studied. The delimitations, expected outcome and outline of this study will be presented in the end of the chapter.*

## 1.1 Background

The strategic importance of the purchasing function is steadily increasing within companies (van Weele, 2010). One primary reason can be related to that the purchasing function is responsible for a major part of the expenditure of the end product or service. This means that purchasing has a considerable impact on the company's bottom line (Gadde et al., 2010). Changes in the international competitive landscape due to decades of globalization, fast development of information technology and ever-increasing customer demands are putting pressure on companies to re-design their business processes. As a result companies have been distinguishing their core activities from their non-core activities. Where the non-core activities are to an increasing degree outsourced to specialist suppliers (van Weele, 2014). The expenditure on suppliers have been increasing over time and is today contributing between 40 to 60 percent of the company's revenue (Stock & Lambert, 2001) and up to 80 percent for OEMs in the automotive industry (van Weele, 2010).

Industrialised economies have for the past 25 years steadily shifting manufacturing away from locations close to home, where home is defined as locations close to corporate headquarters, in a pursuit of lower costs in emerging economies. A country that particularly has been in focus is China where the labour rates at first have been dramatically lower, which has offset transportation expenses and setup costs. But China's attractiveness as a production centre has alternated in recent years. The appeal for producing in China is currently no longer dependent exclusively on lower costs, but instead shifting focus toward market access and capabilities, including both technical expertise but also a massive ability to scale (Lee & O'Marah, 2013).

One censorious trend affecting global corporation's manufacturing footprints is the regionalization of supply chain strategies, going away from global strategies to a strategy oriented to the three regional mega-geographies Americas, EMEA and Asia Pacific. Drivers for this shift is the realities of distance, politics and cultural work (Lee & O'Marah, 2013).

The purchasing and supply strategies of industrial companies have undergone tremendous changes, one of the changes is pointed towards coordinated and leveraged purchasing strategies especially in many large multi-national companies. Purchasing is being integrated into the

business strategies to enable reaching the most efficient supply chains, where the purchasing strategy addresses decisions regarding make or buy, commodity strategies including single, dual and multiple sourcing, supply base management and supplier relationship management (van Weele, 2014). Suppliers are being challenged to actively participate in product development and to support companies' product and market strategies with the goal to create the most efficient and effective value chain possible in order to fulfil the end-customer's needs and expectations (van Weele, 2014).

## 1.2 Introduction to the case company

This master thesis is done on behalf of the Direct Material & Program Purchasing function of Volvo Car Corporation in Gothenburg, Sweden, henceforth referred to as DM&PP. Volvo Cars Corporation, henceforth referred to as Volvo Cars, is a global automotive company with presence in 100 countries, which in 2015 sold 503 127 cars and employed 28 485 people.

The sales are segmented by markets where China, Sweden and US are the currently biggest markets together contributing to 44.3% of Volvo Cars' total sales in 2015 (See figure 1.1 below). The long term 2020 vehicle sales goal is 800 000 cars and the company's vision is to be the world's most progressive and desired premium car brand. In 2014 the company launched it's all new XC90 based on a new Scalable Product Architecture (SPA) with the intention to continue launching new products on that platform all the way in to 2017. Volvo Cars launched the S90 and V90 car model in early 2016 and will continue with more car models coming year. A second platform for smaller cars named Compact Modular Architecture (CMA) will be released in 2017 for the smaller car models in the 40 cluster, like the V40. The ambitious goal for vehicle models is to replace all current car models until 2020.

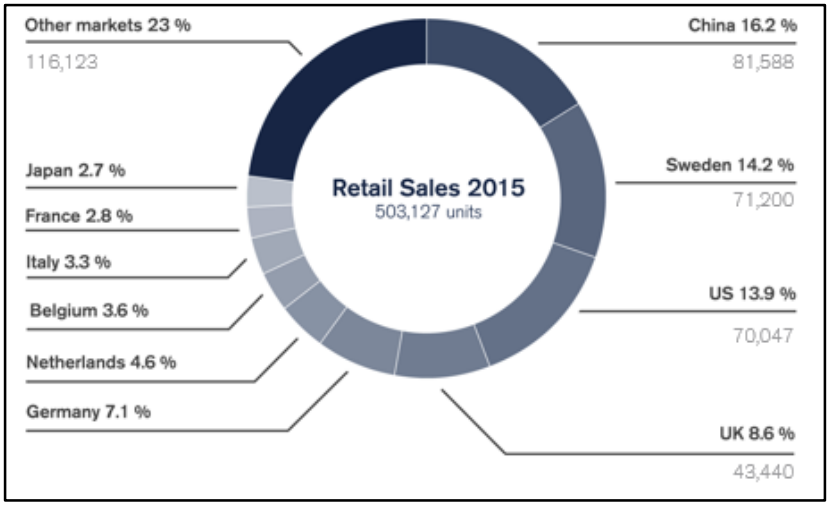


*Figure 1.1. Volvo Cars' Top Ten Markets – 2015 (Volvo Cars Corporation, 2016a)*

The Volvo cars are currently built in four countries where the two biggest plants in terms of production volumes are in Torslanda, Sweden and Ghent, Belgium. A smaller assembly plant

operates in Kuala Lumpur, Malaysia and since 2013 Volvo Cars have commenced production in several plants in China (Volvo Cars, 2016a). Volvo Cars is expanding its manufacturing sites worldwide, with the first American factory being built in South Carolina, USA. When the US plant is up and running in 2018 Volvo Cars will have assembly operations in all the three regions Americas, EMEA and Asia Pacific (See figure 1.2 below).

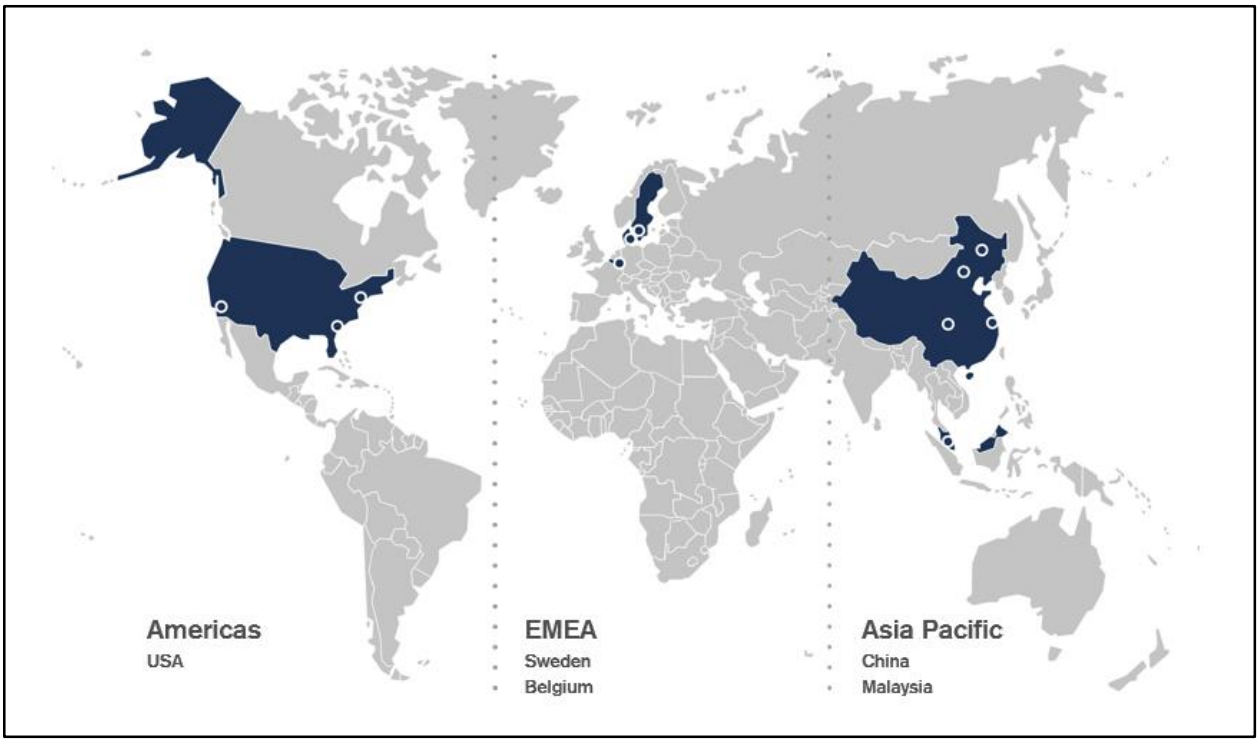


*Figure 1.2. Volvo Cars global presence and manufacturing footprint in the three regions Americas, EMEA and Asia Pacific (Volvo Cars Corporation, 2016a).*

Geographical expansion increases global complexity where the primary complexity is created by an increased manufacturing footprint. When cars are produced at several regions, in Volvo Cars' case soon to be three, Volvo Cars will use equivalent components at multiple assembly plants. With increased manufacturing footprint he question of how many suppliers to have becomes increasingly relevant, and since Volvo Cars to a high degree owns the production tooling such as moulds, dies, fixtures, jigs and such machine tooling used in manufacturing processes at supplier sites, this in term initiates questions regarding the number of production tooling sets to own.

### *Illustrative example 1. A production tooling scenario for a car component:*

*The subframe car components have historically been global sourced from one supplier using one set of production tooling (also known as single tooling) from Europe to supply European and Asian manufacturing sites. As Volvo Cars is steadily increasing its volumes in China and hence deplete higher amounts of the subframes there is a need to investigate if an investment in a second set of production tooling (also known as double tooling) placed in Asia Pacific can make a business case. A business case means that two scenarios are compared (send the subframes from Europe*

*to China or localize supply in China using double tooling) and where the most financially beneficial scenarios is chosen. In the future, as Volvo Cars is starting production of cars in US and the volumes ramp up over there, Volvo Cars might as well consider triple tooling as a potential scenario in the business case. A supplier in each region is a part of Volvo Cars' localization strategy with the goal to have suppliers as close as possible to the assembly site (Vice President DM&PP, February 10th, 2016).*

## 1.3 Problem Analysis

Increased manufacturing footprint in turn also increases the supply base (Volvo Cars, 2015a). One way to manage the increased supply base is to offer Volvo Cars approved and well-performing suppliers the possibility to move along Volvo Cars in its expansion if they can offer products and services with the same service level at competitive pricing in the new regions. The supplier's decision to start produce locally in the new region additionally to their current production in home region or alternatively to ship from home regions are usually considered in the business case presented in the quotation stage in Volvo Cars' sourcing process. In the scenario where a product is produced at several locations a decision regarding single, dual or multiple production tooling needs to be taken. An effective decision model for choosing production tooling setup is of strategic importance and hence will this thesis investigate the current decision making model regarding production tooling understand its driving factors and spot areas for improvement.

In 2013 there was an internal organizational merger of the Manufacturing function and the Purchasing function. The rationale behind this move was to gain control in the value chain and to improve the efficiency and cross functionality of the organisations supplying and focal operations. The rationale is fulfilled by utilizing synergies between the two functions in terms of reducing complexity and cost as well as optimizing the flow in the value chain (Volvo Cars, 2016c). The purchasing function have an important role within Volvo Cars, because they are responsible for the purchasing of all components and services used in production, both direct material, which is material used in in the final product and indirect material, which is products and services needed to run the company but not part of the final product. Approximately 40% of the total cost of a car is Volvo Cars added value including processing and freight cost. The remaining 60% is purchased from external suppliers, this implies that successfully implemented synergies has great potential for improvement on the company's bottom line (Volvo Cars, 2015a). Data pointing in the direction of success for the internal organizational merger of Manufacturing and Purchasing can be shown in Volvo Cars' result figures for the full year of 2015 where the company managed to triple its profit compared to previous year where a significant part comes from the cost savings from purchasing.

This study will focus on the Direct Purchasing and Program Purchasing function of Volvo Cars, responsible for the supply of all components mounted in a car, where one of the issues under the rapid global expansion of manufacturing plants is regarding the number of sets of production tooling, where a single set of production tooling for components is sometimes not enough when the components produced by a specific tool is used in more than one assembly plant. As production tooling is one of the most costly element of a car project, decisions for instance,

whether to have single, double or even triple sets of production tooling for a component are critical for the management team to make.

*Illustrative example 2. The relation between costs of a component compared to a production tooling set:*

*A component is a manufactured good that will undergo no further physical changes, but be incorporated into a system with which there is a functional relationship by joining it with other components. A component is built into an end product and can be sorted into two distinctive groups. Firstly there are specific components, which are produced according to design or specification of the customer. And secondly there are standard components produced according to the supplier or an industry standard, which for example can be sold to competing customers (van Weele, 2014). The price of an average car component is in the 100-10 000 SEK category whether the price of one set of production tooling for the component is in the 10-100 MSEK category. And the lion's share of the specific components require its own tooling set (Commodity Buyer, February 224th, 2016).*

Volvo Cars has a sourcing model, which is the model used when analysing quotations from different suppliers during the supplier selection process. This sourcing model considers, in short, the piece prices and volume of the component and its landed cost, the supplier's potential design & development cost and the price on the investment in sets of production tooling. When the costs are summed up and compared the supplier with the lowest price over the cars' and hence also the component's life cycle is chosen and contracts can be signed. In the case of a multiple tooling setup possibility the business case for single tooling is compared with a business case of having multiple set of production tooling in a Time Adjusted Rate of Return (TARR) analysis. The management at DM&PP have indicated a need to investigate if additional parameters such as lead time, flexibility and tied up capital, can be added to the sourcing model to make Volvo Cars take better decisions regarding the number of sets of production tooling. A figure describing the connection between the additional parameters and the TARR analysis is presented in figure 1.3 below. If the parameters are shown to be suitable they can be integrated and deployed in the sourcing model and be considered in future decision making.

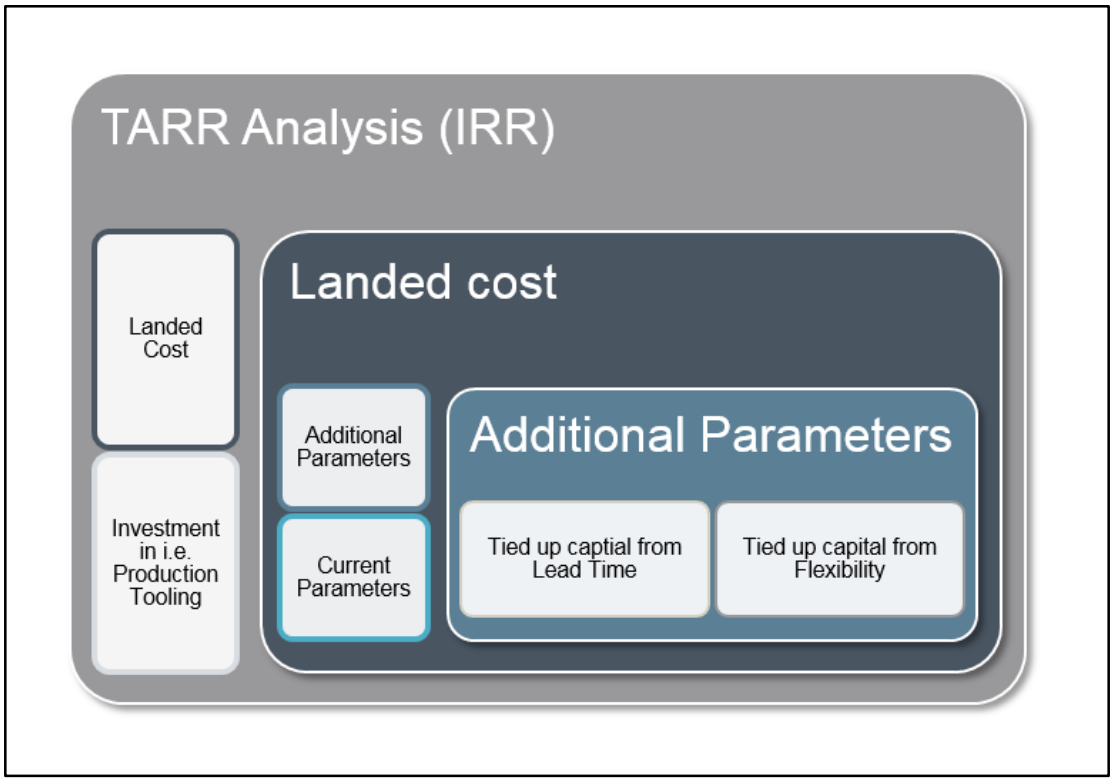


*Figure 1.3. The connection between the additional parameters and the TARR analysis.*

*Illustrative example 3: TARR analysis*

*Volvo Cars uses global sourcing from Korea for high voltage batteries in their hybrid engine car models. This means that a single set of production tooling is needed for producing those battery pack components. The battery packs are then send from the supplier to Volvo Cars' assembly plants in Europe and China where they are used in the car models produced at those assembly plants. Volvo Cars' TARR analysis is comparing the investments associated with multiple production tooling versus the saving in the landed cost by localizing the production tooling. The TARR analysis currently shows that the single tooling setup is most cost effective at the moment. The rationale is that Volvo Cars cannot find a business case for a double tooling setup and hence have decided to ship the high voltage batteries from Korea to Europe (Vice President DM&PP, February 10th, 2016).*

## 1.4 Purpose of the thesis

The purpose of the study is to create a revised model of the existing sourcing model at Volvo Cars. The aspiration is particularly to come up with a revision of the decision model encompassing production tooling. The model should be utilized by Volvo Cars to handle the decisions regarding production tooling for components used at several regions and will in explicitly consider how parameters such as tied-up capital from lead time and flexibility can be taken into consideration in a revised model. To understand how Volvo Cars' current sourcing model is applied within the

organization this study will be based upon looking at historical sourcing cases on five commodities within Volvo Cars' DM&PP organization.

### 1.4.1 Research questions

The project aims at improving the decision making process at Volvo Cars in regards to production tooling in the situations where components are used in more than one production region, therefore, the research questions is proposed as follows:

---

*RQ1:*

*How do an automotive manufacturer take production tooling decisions when cars are produced in more than one region?*

*RQ2:*

*How much influence will the additional parameters of capital tied up from lead time and flexibility have on the existing production tooling decisions for an automotive manufacturer?*

---

## 1.5 Scope and delimitation

This study will focus on the sourcing process within the field of purchasing. The study is primarily limited to analysing the production tooling for the five commodities of Volvo Cars showed in the table 1 below. A Volvo car consist of up to 30 000 components all of them except the ones within the five commodities will be neglected in this study. Research is limited on how to choose commodities in this type of case study, hence have the authors recommended a framework to consider when choosing the commodities. The Vice President of Purchasing at Volvo Cars have used the framework as well as qualitatively targeted five commodities interesting to analyse based on the rationale presented in the below table. This study is delimited to parameters such as tied up capital from lead time and flexibility.

Table 1. List of commodities and the rationale behind the choice of them.

| Commodity | Rationale |
|---|---|
| Steering Wheels | Complex product, quote high value, quality sensitive, labour intensive, questionable if feasible for transport. |
| Seats | Very complex product, final seat assembly must be localized due to sequenced production. Sequenced production due to high variation. |

| | |
|---|---|
| Subframes | A large component, expensive to transport and exposed to a lot of engineering changes because it holds up the propulsion powertrain, which has frequent changes in specification |
| High voltage batteries | Very high cost per piece, battery-cell supply base based in Korea. Currently shipping batteries packs from Korea to Europe. |
| Fuel Tanks | Large component, transport of lot of air. High investment commodity. Today localized in Europe and China. Might be a business case to localize in US as well. |

## 1.6 Expected outcome

This master thesis is expected to result in the following three deliverables desired by Volvo Cars. Firstly a case study of each of the five commodities comparing the production tooling decision taken by the currently used sourcing model with the decision taken by a revised model including additional parameters. Secondly a presentation for Volvo Cars on the results of the case study, in this case, whether to global source (purchase/produce tooling in on region and ship components to the others) or localize (purchase components and have tooling from local suppliers in each region) the production tooling for components used at multiple production units across Volvo Cars' production regions. Thirdly a proposal of a revised sourcing model or framework will be created primarily considering adding parameters such as tied-up capital from lead time and flexibility for future production tooling decisions.

# 2. METHODOLOGY

*The following chapter presents the different theoretical notions and approaches that have been applied in this study and how the research process have been carried out. The data collection comprises both empirical data collection and the literature study, the combination provide a base for achieving the purpose of the research and provide an insight to the research question.*

## 2.1 Research Approach

The purpose of the research approach, according to Davidson and Patel (2011), is to give an overall description of how theory and empirical findings will be related to one another. They (Davidson & Patel, 2011) have pointed out that the purpose of research approach is to demonstrate an overall view of the connection between the empirical data and theory, they have also mentioned that there are three different research alternatives, namely deductive, inductive and abductive approaches. Since the main part of this research will be based on empirical findings and academic resources, it is important to understand the connection. In a deductive approach, both theory and common principles are used to come up with hypothesis about special cases and test these against reality, using collected empirical data (Davidson & Patel, 2011). A deductive approach means that the research is based on the theory, meaning that an existed theory is tested in order to assess its validity (Bryman & Bell, 2011).An inductive approach is the generation of theory from research, meaning that new theory is based on the findings of a study (Bryman & Bell, 2011). When using an inductive approach, theories are formulated toward the end of the research, by drawing general conclusions from observation of the collected empirical data (Goddard & Melville, 2001). The results drawn from this approach is based on a period of study where patterns and experiences are obtained during the process. Lancaster (2007) states that an inductive approach essentially reverses the process found in deductive research, where the abductive approach, on the other hand, combines the inductive and deductive approach. Wallen (1996) claims that the combination of inductive and deductive approach makes it freer and possible to adapt.

In order to better understand different situations for decision making, and to develop a sufficient scope of the project, the researchers decided to use scenario planning approach for the analysis. Wade (2012) pointed out in this literature that scenario planning is a productive and creative way of developing groundwork for strategic plan that does not bet company's future on an emergence of single "most likely" scenario. The outcome of scenario planning process is a portfolio of future scenarios, each representing a different way the business landscape could look in a few years. (Wade, 2012). Wade also added that the scenario planning does not reveals tomorrow's mystery, but rather, to open the sight of how future could develop in the future, and with these insights, companies are be able to make more flexible and better decisions. The scenario planning approach and process for this project case will be introduced in detail in the research process section.

Referring to the research approach, that an abductive research will be applied to this study in order to generate a result. The researchers in this case will start the process by collecting,

analysing data and applying the existing theories in order to assess the validity. With a combination of empirical study, the researchers get input from the reality to make the study more case sensitive. A deductive approach will be utilized in the process to generate a more case-based theory for the reality.

## 2.2 Research Process

The research process started by defining the scope of the project with the principal management at the case company parallel with discussions with this study's academic supervisor, to make the width and depth of the research distilled, explicit and coherent. The initial start-up meeting was with the high level manager at the company in order to get a helicopter view of the situation and decide the direction of the project. More specifically, the Vice President of the Direct Material & Program Purchasing organization started by suggesting commodities that are appropriate to analyse. The researchers took in the suggestion as an empirical data, and together with the statistical model and calculations, the five commodities were decided for the data collection. The historical sourcing data from archives and systems, including the production tooling decision process will be reviewed together with the responsible buyers, so as to understand the decision making process and identify areas of improvement. Since there will be more parameters added to the model, ex. Tied-up capital from lead time and flexibility. The researchers at the same time arranged meetings with different key person that is specialist in taking considerations of these parameters and thus found a solution to integrate the additional parameters into the existing sourcing model. The detailed process of historical data analysing and the interviews with different key responsibilities will be introduced in the data collection section. An illustration of the research process and the connections to the chapters of this report can be seen in figure 2.1 below.

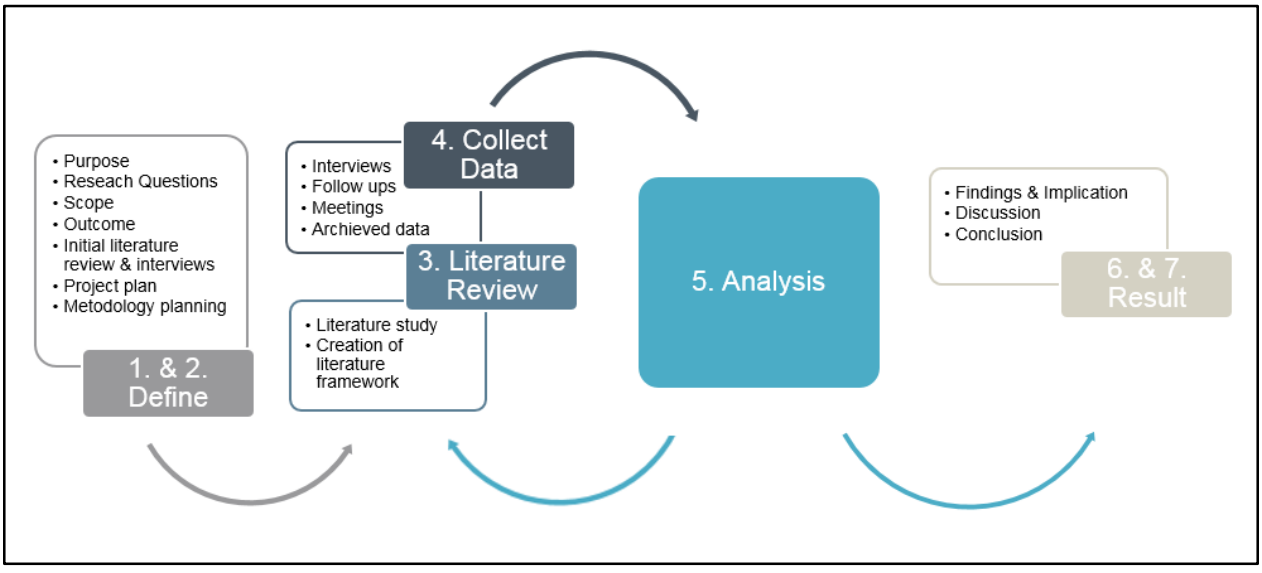


*Figure 2.1. The research process and the connection to the chapters in the report*

As mentioned in the previous section, the scenario planning has been implemented in the research process, to understand the full picture as well as provide insight to what alternatives the decision makers would face in the future. The scenario planning is grounded from the global strategy at Volvo Cars that the company's footprint should be exist in the Americas, EMEA and Asian Pacific. The possible scenarios the decision makers would have to deal with for the production tooling can be divided into seven production tooling scenarios, illustrated in the figure 2.2 below. For each of the five commodities the current production tooling decision was analysed and compared with a different but possible scenario using the existing model as well as using a revised model including the additional parameters to test how much influence the additional parameters of capital tied up from lead time and flexibility could have on the existing production tooling decision and to understand if the production tooling decision would be changed if additional parameters would be added to the sourcing model.

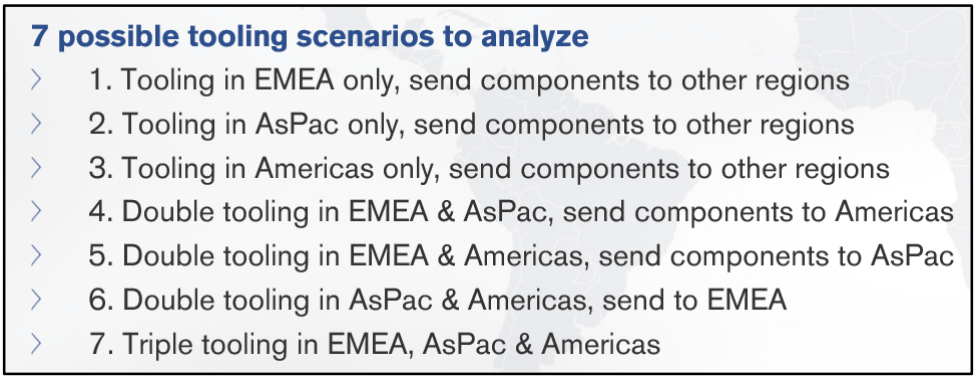


*Figure 2.2. The seven possible production tooling scenarios to analyse.*

## 2.3 Description of methods

Multiple methods will be applied to this thesis work, the authors will start by literature review of the possible research fields from the chosen topic, and at the same time, relevant and historical studies will be reviewed to find out which area should be focused in the studies. Empirical data will primarily be gathered by semi structured and unstructured interviews with staff at Volvo Cars and if needed with external resources. The authors will furthermore gather and analyse data extracted from systems and archived databases at Volvo Cars.

The research must be done in a tight collaboration with the company to ensure a sufficient communication level with the management team and employees involved in the decision making around production tooling at the company along the way, and to deeply understand the issues at hand. Jarzablowski (2002) emphasizes looking at the point of creation of how strategy actually is created to understand it. Therefore, action research will be a suitable approach for the research, as Bryman & Bell (2011) suggests that action research is an approach where the researcher works together with the organization in order to solve issues that concerns them in an iterative process of problem identification, planning, action, and evaluation, which helps the researchers to change patterns of thinking and identifies new possible actions to take. This iterative approach is in line with an abductive approach which will be followed in the research. Action research often

combines a variety of research methods in the process of conducting research. Semi- and unstructured interviews, observations and focus groups will be performed as the research needs empirical data and will be performed through collaboration with employees. Internal documents will be largely used in this research case, since the topic is tightly connected to the organization and many organizational documents will be used as an information base for the research.

### 2.3.1 Literature research

Literature research method is applied as a means to investigate what studies has been done in this field before and to get a thorough understanding of the chosen research question in order to formulate it in a more sound way. The articles chosen for the research will mainly be from the Chalmers Library database and also Google Scholar.

### 2.3.2 Participant observation

The participant observation was applied during the study, meaning that the researchers paid an attention to the participants on their natural habitat while bearing in mind on their cultural context. As Bryman & Bell (2011) mentioned that participant observation make it possible for the researcher to better understand use of words and to get other information that the person under study takes for granted and does not speak verbally during an interview.

### 2.3.3 Unstructured interviews

In an unstructured interview, the interviewers do not follow a strict structure of questions, but instead might have only one or a few questions for the interviewee. The interview therefore resembles a conversation. (Bryman & Bell, 2011) Some of the meetings with the purchasing team at Volvo Cars were conducted in unstructured interviews.

### 2.3.4 Semi-structured interviews

In total, 35 interviews were held. All of them interviewed Volvo employees from different levels and from different organisational departments. A record of all interviewees is listed in the table 2 below. The majority of interviews with buyers has been through a semi-structured approach, the benefits of having semi-structured interviews is that the interviewer can observe body language and more easily interact with the interviewee. Additionally, the interviewer has better control of the interview situation (Bryman & Bell, 2011). Additional interviews and follow-ups have been performed more unstructured with the focus of ensuring sufficient data gathering in terms of archived data and systems from previous sourcing decisions involving production tooling.

*Table 2. List of interviewees, date of interview, role of interviewee and interview topic.*
(See following page)

| Job Title/Meeting | Date | Topics & Key take away |
|---|---|---|
| Vice President DP&PP | 2016-02-10 | Background, Purpose, Scope |
| Senior Purchasing Manger, Body & Stamping | 2016-02-12 | Initiation, Project review |
| Commodity buyer, Body & Stamping | 2016-02-16 | Information about sourcing process |
| Commodity buyer, Body & Stamping | 2016-02-16 | Sourcing model vs. Sourcing template, difference between Electrics & Body & Exterior, Sourcing template not applicable in all sourcing situations, especially not in electrics department. |
| New Sourcing Template introduction. | 2016-02-16 | New sourcing template with the possibility to do document triple tooling analysis. |
| Product Buyer, Body & Stamping | 2016-02-17 | Information regarding sourcing approach and sourcing consensus meeting for one commodity. |
| Product Buyer, Body & Stamping | 2016-02-24 | Discussion around the purpose of going for multiple tooling. Robert also informed about the organisational merger of the direct material och program purchasing departments. |
| Commodity buyer, Body & Stamping | 2016-02-24 | Described the connection between TARR and savings in landed cost when going for multiple tooling. |
| Buyers of Subframes | 2016-03-05 | Additional data gathering about commodity |
| Buyers of Fuel tanks | 2016-03-05 | Additional data gathering about commodity |
| Buyers of High voltage batteries | 2016-03-05 | Additional data gathering about commodity |
| Buyers of Subframes | 2016-03-05 | Additional data gathering about commodity |
| Buyers of Steering wheel | 2016-03-05 | Additional data gathering about commodity |
| Senior Logistics Engineer Landed Cost (C&A) | 2016-03-18 | Information about landed cost model and drivers for tied-up capital from a MP&L perspective. |
| Project Manager, Value Chain development | 2016-03-18 | Flexibility/Responsiveness from a MP&L perspective. How to quantify flexibility towards production. |
| Purchasing planners, Aftermarket | 2016-03-18 | Description about a project about production tooling, for aftermarket components. |
| Buyer Subframes | 2016-03-18 | Current tooling decision and description about the commodity. |
| Project Manager, Value Chain development | 2016-03-29 | Safety Stock based on normal distribution |
| Direct Material & Program Purchasing Q1 - Town Hall Meeting | 2016-04-03 | Presentation for all purchasing employees at DP&PP. Full year of 2015 financial results and DP&PP KPI follow up. |
| Buyer Fuel Tanks | 2016-04-04 | Current tooling decision and description about the commodity. |
| Commodity Buyer Fuel Tanks | 2016-04-04 | Sourcing and Production tooling decision of Fuel tanks for the SPA platform. |
| Commodity Buyer Steering Wheel | 2016-04-07 | Sourcing and Production tooling decision of Steering wheels for the SPA and CMA platform. |
| Commodity Buyer Subframes | 2016-04-07 | Sourcing and Production tooling decision of Steering wheels for the SPA and CMA platform. |
| Buyer Steering Wheel | 2016-04-11 | Current tooling decision and description about the commodity. |
| Sourcing Council Meeting, Stamping, Fuel Tank | 2016-04-11 | Presentation, market test for EU+US dual sourcing. |
| Sourcing Council Meeting, Stamping | 2016-04-11 | Follow-up presentation of US sourcing, only 1 supplier, US Plant Manager not happy. |
| Buyer High voltage batteries | 2016-04-12 | Current tooling decision |
| Global Council Meeting Seats | 2016-04-18 | Current tooling decision |
| Buyers Seats | 2016-04-25 | Front Structure of Seats |
| Senior Logistics Engineer Landed Cost (C&A) | 2016-05-09 | Additional input, Landed cost model including tied-up capital |
| Project Manager, Value Chain development | 2016-05-09 | Additional input, Flexibility/Responsiveness, |
| Supply Chain Management Finance | 2016-05-16 | Tied-up capital scenarios, input in lead times and standard deviation of lead times. |
| Purchasing Controller | 2016-05-26 | Tied-up Capital and TARR |
| Direct Material & Program Purchasing Q1 - Town Hall Meeting | 2016-05-27 | DP&PP cycle plans and purcasing program management |
| Purchasing Controller | 2016-05-30 | WACC and TARR |

### 2.3.5 Analysis of data

In the data analysis phase, all data from systems, archived data and interviews were analysed. The analysis was done in the following four steps.

Four steps analysis:

1. Qualitative interview data analysis
2. A comparison of the identified scenarios and its corresponding business case for each of the five commodities with existing parameters from current sourcing model
3. A comparison of the scenarios and its corresponding business case for each of the five commodities with the revised model including the additional parameters
4. Analysis of the between the revised and the existing model and consequential implication

### 2.3.6 Confidentiality

The data collected from the case company that is sensitive for publicity will due to this reason be anonymized or systematically changed to not disclose any confidential information. The result from the analysis part will conclude the same rationale and direction of recommendation as the results from the analysis with the real figures and numbers and will not in any way be distorted only anonymized.

## 2.4 Ethical considerations

There are four main ethical principles that needed to be taken into consideration during the research process, according to Diener and Crandall (1978) they can be described as follows:

1. Whether there is harm to participants.
2. Whether there is a lack of informed consent.
3. Whether there is an invasion of privacy.
4. Whether deception is involved.

Additionally, there are further ethical and legal considerations stated by Diner (1978), Data management and protection, copyright, reciprocity and trust and affiliation and conflict of interest. The following paragraph will be developed according to the four ethical principles and other legal and ethical aspects.

#### 2.4.1 Harm to participants

The researchers have the responsibility to ensure that respondents are in no way directly harmed or adversely affected. Harm is interpreted in a broad terms, including both physical and psychological harm (Bryman & Bell, 2011). According to Diener (1978), Harm can also be interpreted as damaging their development or self-esteem, Causing stress, Harm to career prospects or future employment.

There are no physical harmness during the research and interviewing process. Still, when it comes to the psychological harmness, there is a risk that the interviewees experience some levels

of stress. The stress came from the fact that the interviewees had to discuss their opinions on certain product groups and their personal opinions that they may not willing to tell. The possibility of having harm on other aspects is kept on a rather low level, as all the discussions, interviews, and results presented are based on a logical and statistical analysis. Personal and emotional feedbacks is rather for the data gather in this project. The harm for future career development is nearly zero, as everything is transparent and based on the discussion with higher managers, to get higher management commitment before moving forward in the process. So the management is fully aware of the decisions made in the project and the researchers together with the company participants developed sufficient commitment and trust during the process, which can be a positive add-up to their future career plans. In order to mitigate the stress and anxiety from the participants, all the interviews are coded anonymous, and made it impossible to trace back answer or quotes from each of the individuals.

### 2.4.2 Lack of informed consent

Informed consent means the researchers need to be sure to give as much information as might be needed to make an informed decision about whether or not to participate in a study.(Bryman & Bell, 2011) All the interviews, including with supervisors from the academic side and from the company side, were on a voluntary basis. Additionally, when researchers sending out emails to ask for information, it will always been mentioned in the mail that the participant are free-willing to answer the questions.

Ahead of all the interviews and discussions, the researchers made plans to prepare the participants as good as possible, to give enough background information, and also to have a clear agenda about the meeting, so the participants are aware of the content of the meeting as well as the meeting plans, therefore to be able to make decisions on whether to join the meetings. It will also be clearly announced before the meetings whether it will be recorded. One notable aspects is that, it is depending on the person and type of questions the researchers are planning to take up to the meeting that is decisive of what is “enough” information. And it is extremely difficult to present prospective participants with absolutely all the information that might be required to make an informed decision (Diener, 1978). The researchers keep a live discussion with the participants and the information exchange in between is well maintained, and it have not been observed that the participants felt uncomfortable about the coming questions, which can be seen as an indication of well-informed consent for the interview.

### 2.4.3 Invasion of Privacy

According to Diener and Crandall (1978), It is important that not to intrude on a respondent’s privacy nor to abandon normal respects for an individual’s values, and that the individuals should have the right to refuse to answer certain questions; This principle requires the researchers to treat each case sensitively and individually, and give the respondents a genuine opportunity to withdraw.

As it was mentioned earlier, all the interviewees involved in the process will be informed in advance about the topic and a brief content of the interview, the interviewer will also be informed about their right to not answer certain questions during the interview process, and the reason will

be notified by the researcher as a limitation of the research. To protect the anonymity and the privacy of the participants, no names will be taken on the note, however, the title as well as main role of each participant will be noted for the research in order to make the information more trustworthy.

### 2.4.4 Deception

Deception is the fourth ethical principles that were considered in the research process, by definition from Diener and Crandall (1978), it means, not representing the research as something other than what it is. All the information that are noted from the interview will be send to each participant to make sure there is no misunderstanding from the interview and at the same time to ask for the permission to utilize the information, or if they wish some of the content need to be adjusted or deleted. For some interviews where the recording equipment can be used, the participant will be informed about it before the interview starts, and the permission must be given from the participants before the recording equipment are applied.

## 2.5 Trustworthiness

The trustworthiness of this research need to be considered as various qualitative research were involved in the process. According to Bryman & Bell (2011), there are four criteria which can be characterized into four individual questions and they will be used as a base to argue for the validity and reliability of this study. The four questions, stated by Bryman and Bell (2011) are shown below:

- Credibility: How believable are the findings?
- Transferability: Do the findings apply in other contents?
- Dependability: Are the findings likely to apply at other times?
- Conformability: Has the investigator allowed his/her values to intrude to a high degree?

### 2.5.1 Credibility

As it was described in 2.3, all the interviews are either recorded or noted by the interviewers, in order to make sure the empirical data from the interviewees are not missed. The quality check of the interview content have also be carried out in the end of each interview, that the content are either showed to the participants in the end of the interview, or it have been sent to the participants to get confirmation. If the interviews were recorded, the interviewer will re-play the recording, note down the information and double check with the participants in order to make sure the content are clearly understood and no personal values of the listener are being involved.

The comparison method was also applied in the data quality checking process, that the content noted from one interviewee will be re-mentioned in the following interviews where other participants are involved. The purpose is not to get exactly the same answer, but rather to understand the question from another perspective, and therefore to minimize the objective answer from the participant to the largest extent.

### 2.5.2 Transferability

The researchers are paying attention to the transferability of the empirical data by describing empirical data and the contextual settings in detail, to make sure that the transferability criterion is met. As there were five commodities chosen for the research base, the researchers have made efforts to clearly state the contextual settings and criteria that have been used for choose the five product categories, and the reason for the criteria have also been described. Since the background setting in this case at Volvo Cars is that the company is planning to have three main global locations, which are Asia Pacific, Americas and EMEA. The criteria may be changed when it comes to another setting where the global locations are updated, and could therefore have an effect on the ultimate chosen commodities.

### 2.5.3 Dependability

A research model have been outlined in the beginning of the research to make sure that all the plans are strictly targeted at the purpose of the study, the model have been kept as a live document, and have been updated during the process. All the interviews and document have been noted with a reason, so the logic behind each action can be tracked and understood.

### 2.5.4 Conformability

As it was mentioned in the trustworthiness questions, the conformability means the research itself should not be affected by the researchers' own values and should be kept subjective, although it have been noted that the risk of having influence from the individuals still exists. As the risk exists in the interviews with the employees from Volvo Cars, especially when there are only one person involved in the interview, it is hard for the interviewees verifying the reliability of the information due to lack of knowledge. However, the situation are improved when there are several people involved in the interview, it have been noted that the speaker tend to verifying his/her words with the colleagues, and colleagues ask questions or give comments to the information from another speaker. This interaction between the interviewees make it easier for the interviewer to understand the information from different angles, and to mitigate the risk of involving too much of one person in the empirical data.

### 2.5.5 Reflections on limitations in the research method of case studies

Since this study is performed by applying the method of case studies the authors would like to reflect on the uncertainties accompanying this type of research method. The fact that this study is delimited to five commodities and then choosing one historical sourcing for one variant or incremental subcomponent of those commodities brings up the question of trustability. The choice of the five commodities to focus on was made by the top management at DM&PP at Volvo Cars and the top management have chosen these because they believe those five commodities are interesting to shed light upon. Since each commodity is rather specific and differs from one another the authors avoid making any generalisations and will not draw any conclusions by comparing the commodities to each. The collected and analysed data will be used as a whole to investigate the impact of the added parameters on the sourcing model. To make generalizable results and conclusions from this study further case studies is needed. There is a time span of

roughly four year from the oldest to the newest sourcing case and this can bring up a question regarding uncertainty. The authors did however emphasise during the interviews with the buyers to focus on the buyer's most recent sourcing so that the most recent data could be used and so that the buyers could recall, pinpoint and explain the different sourcing processes and events during these processes. The data collected from systems and achieves should be seen as less uncertain.

# 3. THEORETICAL FRAMEWORK

*Following chapter folds out the theoretical framework applied in the analysis of production tooling decisions which are a part of the sourcing of car components in this study's automotive OEM contextualization. The first section covers purchasing and its primary tasks and processes followed by various sourcing strategies that organizations generally apply to their sourcing activities. The chapter further elaborates on theories of relationships between the buyer and supplier. The financial side of purchasing will also be introduced in this chapter such as working capital in terms of lead time and flexibility. The necessary financial terms for production tooling decisions have been illustrated in the section with the theories of landed cost, and time adjusted rate of return. Regionalized supply chain theory are introduced in order for the readers to have a global perspective on purchasing and to gain an overall understanding of the global context.*

## 3.1 Purchasing

*This section entails an introduction to purchasing, the tasks and responsibilities of the purchasing organization followed by a presentation of the purchasing process, with the aim of guiding the reader to the field of Sourcing, which is the theoretical area within Purchasing this study primarily is going to cover.*

Purchasing is emerging as an eminent part of supply chain management and refers to the management of an organization's external resources to secure the supply of all necessary goods, services and information. The supply needs to be secured to ensure efficient operations of primary and supporting activities within an organization (van Weele, 2014). The purchasing function has traditionally been known to merely cover the operational part of the purchasing process (van Weele, 2014). In practice this meant that the daily work of a purchaser on an operational level treated orders one by one, where each single order was optimized in terms of quality, price and delivery in isolation. This approach is problematic since purchasing decisions by and large are interrelated and should be optimized on a more aggregated level than solely on single decisions (Gadde et al., 2010). A purchasing decision is generally a part of a series of purchasing decisions and intermittently associated with supplementary contextual transaction costs and investments (Gadde et al., 2010). In this study's automotive contextualization the authors will be denoting the buying organization's investment in production tooling associated with the purchase of a set of incremental car components.

The importance of purchasing as a strategic area for organizational improvements have been boosted by trends such as outsourcing and focus on core competence. The current ratio of purchasing spend in relation to the cost of goods sold is in the vicinity of 80% in the automotive industry (van Weele, 2014). The increased amount of revenue being spent on purchased goods and services adds to the potential savings that could be realized within the purchasing function thereby increasing the function's importance (see figure 3.1 below). Additional factors adding to the strategic value of the purchasing function is the organizational value contribution gained by involving suppliers in the innovation and product development process. With the increased purchasing spend in relation to the cost of goods sold the responsibility and financial liability the

supplier holds have consequently likewise increased. (van Weele, 2014; Gadde et al., 2010). Because of the proliferated role of suppliers, purchasing's importance surge as well. Gadde et al., (2010) argue that a better phrase for purchasing would be 'management of supply networks' in line with the modern applicability of it.

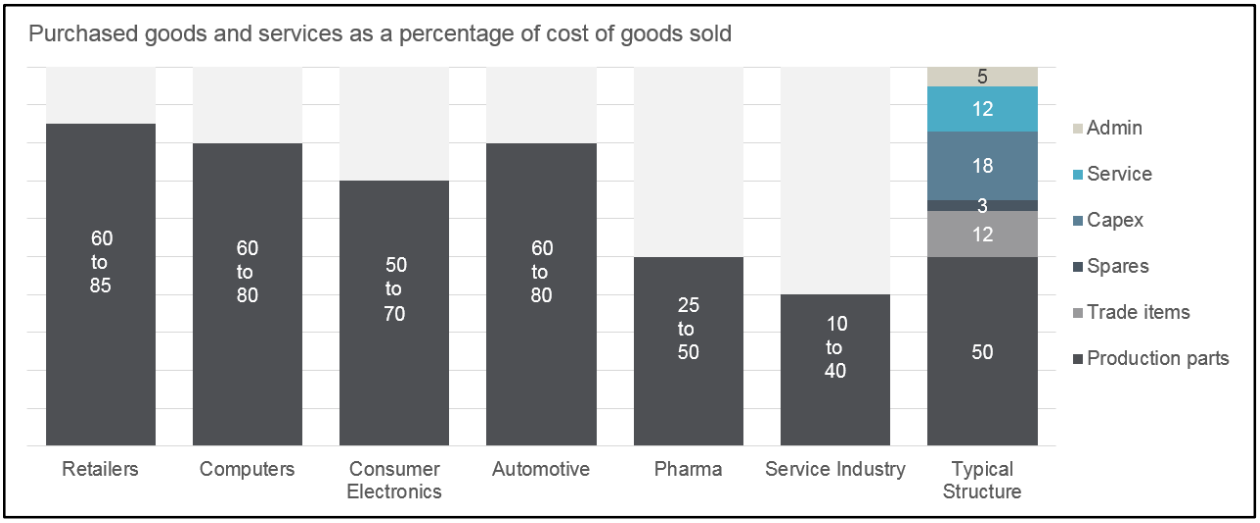


*Figure 3.1. Adopted from van Weele (2014)*

Boosted by the trend of increased supplier responsibility and endowed by the buying organization's quest of shorter time to market and technological availability the in many instances costly process of product development is progressively assigned to the supplier (Gadde et al., 2010; van Weele, 2014). The supplier's product development responsibility is further endowed by the increased pace of innovation along with as the buying organization is becoming to a greater extent specialized and core competence focused (Gadde et al., 2010).
This increased supplier involvement is nonetheless putting buying organizations at accentuated risks soliciting increased need for risk management and mitigation (Norrman & Jansson, 2004; Wang et al., 2010).

### 3.1.1 Primary tasks and responsibilities of purchasing

According to van Weele (2014) there are four tasks, which purchasing departments are responsible for; the supply task, spend management task, risk management task and the development task as described below.

The supply task is predominantly about securing timely and undisturbed availability of purchased goods, services and associated information from reliable suppliers of a consistent quality at a reasonable cost. Effective and efficient supply is mandatory to assure smooth flow of operations and end customer deliveries (van Weele, 2014). The spend management task comprises the control and reduction of the entire organization's purchasing related spend. Goods should be purchased at lowest total cost of ownership or best value, along with reduced indirect costs. Major task is to make sure that materials and services are bought at fair and competitive prices from the

best suppliers available (van Weele, 2014). The risk management task focuses on reduction of company's risk exposure in relation to its supply markets. Avoid becoming too dependent on just a few suppliers, company's management should be compelled to aim for spreading its purchasing requirements among an adequate number of suppliers depending on the context (van Weele, 2014). The development task encompasses the contribution to product and process innovation as suppliers often are a source of new products, services and production technologies (van Weele, 2014).

### 3.1.2 The purchasing process

Depicted in the schematic figure 3.2 below are the main activities within the purchasing function (van Weele, 2014). The six closely interrelated activities consist of following six processes: Determining Specification, Select Supplier, Contract Agreement, Ordering, Expediting and Evaluation. The purchasing function does not cover the responsibilities of material requirements planning, materials scheduling, inventory management, incoming inspection and quality control but are nonetheless closely interlinked to the theses materials activities, if not it is hard for the purchasing function to be effective (van Weele, 2014). This study will mainly focus on the Tactical activities and in particular the sourcing part of purchasing and those activities will be further described in this section. The authors have consequently decided to leave out the theoretical notion of the order function activities.

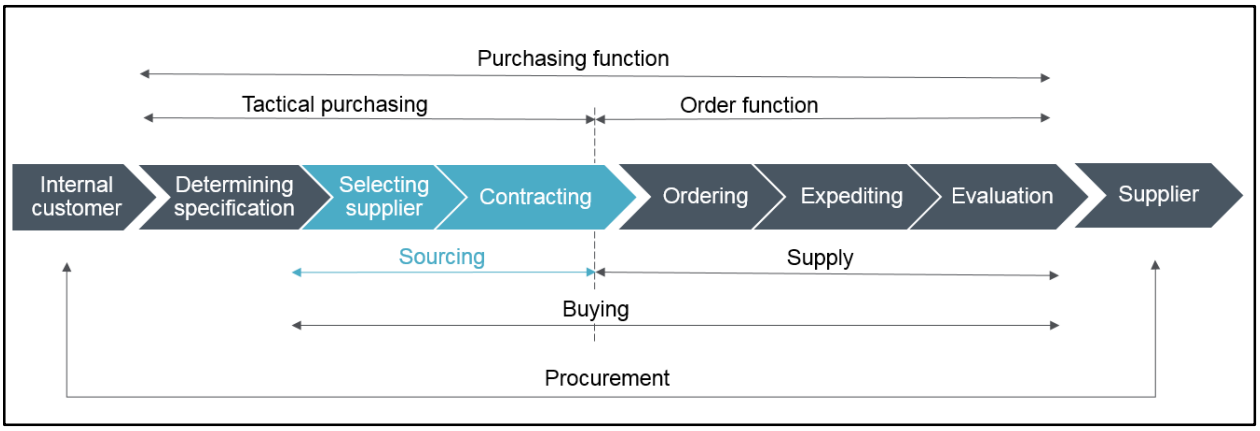


*Figure 3.2. The processes within the purchasing function (adopted from van Weele, 2014)*

Depending on if the activity is a new-task, modified rebuy or straight rebuy, where the purchaser need to start in the purchasing process will differ. New task starts at the very beginning whereas in straight rebuy you just start at ordering process (van Weele, 2014). The processes and activities are controlled by gatekeepers often the buyers and then followed up and decided upon often referred to as by the decision making units (DMUs), usually boards or committees with cross functional middle managers and senior purchasing managers responsible for the approval and follow up of specific purchasing activities. Companies define their purchasing process and uses activities and tools to handle the processes. The processes, activities and tools can be described as a purchasing model (van Weele, 2014). A lot of problems with regards to purchasing decision

making and supplier relationships can be referred to insufficient management of the interfaces within purchasing (see figure 3.3 below) and the lack of organization within the DMU.

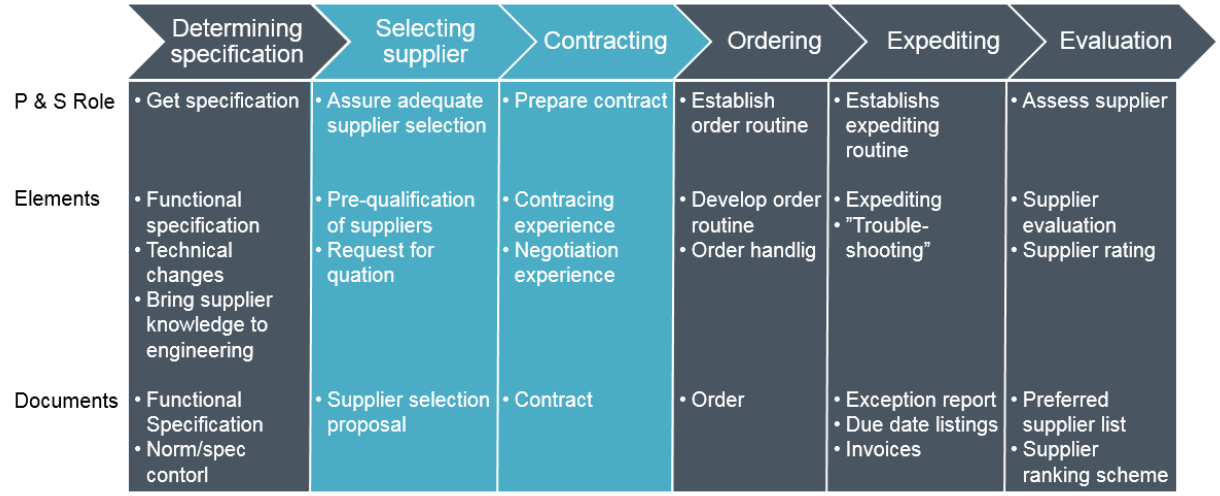


*Figure 3.3. Purchasing process approach and interfaces (adopted from van Weele, 2014)*

## Define Specification

The process of defining the specification requires cross-functional collaboration and input from several departments (van Weele, 2014), in a car manufacturing context this it usually involves, product development, logistics, finance, vehicle strategy, manufacturing, purchasing, and supplier quality to mention a few. Both functional and technical specification are part of a wider concept called *purchase order specification*. This set of documentation encompasses following areas:

- Quality specification, describing the technical norms and standards the delivered product should meet
- Logistics specification, describing the volumes needed, place and time of the delivery including possible packaging, and the physical conditions to be respected
- Maintenance specification, describing the maintenance and service procedure the supplier will be responsible for including possible spare parts carried by the supplier
- Legal and environmental requirements, describing the compliance of health, safety and environmental legislation
- The target budget specification, describes the financial constraints to the solution that should be conformed to by the prospective supplier to be found

The aim of this specification phase is to determine the scope-of-work description and product requirements for an effective solution that can be efficiently provided by a prospective supplier (van Weele, 2014).

## Supplier selection

The supplier selection activities initiates with that the buyer starts the supply market research, which in practise are very much intertwined since when drawing up the technical specification the costs and practical feasibilities are estimated with the names of a few suppliers in mind. The specification activity can be divided in **four steps**. The **first step** involves the decision of method for outsourcing, where the choice of turnkey or partial outsourcing need to be taken. Turnkey means that the supplier is responsible for the entire assignment often including the design for the solution as well. Partial outsourcing means that parts of the assignment is contracted out to often various suppliers, where the coordination lies on the buyer. Partial outsourcing is usually cheaper, but the lower cost can only be materialized if the buyers manages to handle the activities in the project effectively if not it might even result in higher cost than the cost from a turnkey approach. Another choice to make during the first step is how the work performed by the supplier should be rewarded. There are several alternatives three examples are fixed-price and cost-reimbursable basis and unit rate contracts (van Weele, 2014). The supplier selection is one of the most important steps in the purchasing process and the choice of contracting method determines how coming activities are going to evolve, the choice should therefore be made together with the user or budget holder. If room for an investment in multiple sets of production tooling is not made in the budget prior to the supplier selection, in the case of a sourcing of components, the buyer will have hard times presenting a business case going for a setup with more than one supplier.

The **second step** in about the preliminary qualification of suppliers and the creation of the “bidders list”, which is a list of plausible suppliers. To them a request for information (RFI) is sent where the plausible suppliers should demonstrate how they can live up to the purchase order specification and other information enabling them to qualify for the order. It is not uncommon for buying organization to perform supplier audits at this time to qualify and approve suppliers before request for quotations (RFQ) is sent out.

The **third step** is the preparation of the request for quotation and analysis of incoming bids. Based upon the given information the long list is reduced to a short list of suppliers. It is common practice to identify three to five prospective suppliers from whom quotations will be solicited. The suppliers on the short list are requested for quotations where the most promising supplier is chosen for the contract. It is important that the quotations from the different suppliers are comparable in terms of prices, terms and conditions. When the quotations are received the purchasing department performs a preliminary technical and commercial evaluation where they look at and weight aspects such as technical, logistic, finance, legal and quality. The buying organization typically looks at the total cost of ownership (TCO), which is referred to as the total cost over the lifetime of the product. For the buyer to be able to do a TCO analysis the bidding suppliers need to provide detailed cost information (van Weele, 2014).

The **fourth step** is the final negotiation and selection of the supplier who will deliver the product or service. When more than one supplier is used for the assignment there usually is a corporate sourcing strategy behind it. More about sourcing strategies will be described in the following section (van Weele, 2014).

### Contract agreement

Then the supplier or suppliers have been selected a contract will have to be drawn up. The technical essence, commercial and legal terms and conditions will vary depending on the context. Pricing arrangement can differ substantially, but the buying organization is generally preferring a fixed price arrived through competitive bidding because a fixed price facilitates the cost control and budget management. All risks as long as they are not excluded contractually should be accepted and handled by the supplier, which by and large is responsible for adding a risk premium to the fixed price during the bidding phase. In the case of buying from foreign supplier the currency risk need to be mitigated. The exchange rates may differ significantly between the date of signed contract and the date of billing and this need to be handled in the contract. The payment terms will impact the buying organization's cash flow. Payments are in general based on the supplier's performance where the supplier gets paid after fulfilling certain performance measures. Penalty clauses and warranty conditions are stipulated to handle eventual corrective measures in the case of nonconformities of agreed quality, requirements, specifications, conditions, drawings and samples as well as delivery and performance of the product or service. The tug-of-war around purchase and sales terms and condition are sometimes referred to as the “battle of forms”. To make international trade more convenient standardized terms and conditions have emerged. An example of this are the INCOTERMS which are globally accepted series of three-lettered trade term stipulating common contractual sales and purchase conditions (van Weele, 2014).

As mentioned in the introduction to this section the study will focus on the activities within the tactical purchasing activities, which consist of the *determining the specification* and the sourcing processes since it is within these activities a decision regarding production tooling setup is analysed and taken. Sourcing consist of the two processes *supplier selection* and *contract agreement.* The physical possibilities of production tooling setups and size of its investments are critically affecting the total spend of a sourcing case and hence critically affecting the supplier selection process. The buyers are negotiating the prices, tooling investments and, if feasible, exposing the quoting suppliers to competition during the contract agreement process to enable the final decision to be as optimally as possible from the buying organization's perspective.

## 3.2 Sourcing Strategies

*Since this study primarily will be done within the theoretical field of Sourcing a deeper dive will be presented in this section, covering the definition of sourcing strategy and a presentation of its various kinds.*

A sourcing strategy refers to the structures and arrangements of the sourcing of products or services within an organization. A sourcing strategy involve factors such as characteristics of the suppliers, the number of supplier in supplier base for each product or service and how many that should be used, the location of the suppliers, the relationship to the suppliers as well as nature of contracts to be used (van Weele, 2014). Literature imply that the choice of sourcing strategy can serve as a robust and proactive risk management approach (Wieland & Wallenburg, 2012). The implications of the choice of sourcing strategy needs to be evaluated and acknowledged. The

following sections below presents prevailing kinds of sourcing strategies applied in organizations as well as the corresponding implications.

### 3.2.1 Single and Sole Sourcing

Single sourcing refers to the fulfilment of a buying organization's need for a product or service exclusively from a single supplier (Treleven & Schweikhart, 1988). Even though numerous suppliers exist a single supplier is utilized (Blome, 2009). The notion of sole sourcing refers to the sourcing from a single and only available supplier, which in turn implies high bargaining power from the suppliers side (Blome, 2009), which further implies to higher prices due to the absence of leverage from the buying organization. The possibility for negotiation is aggravated compared to the single sourcing scenario where the buyer choose one supplier but has the possibility to test the supplier on the competitive market and hence possibly lower the price or increase the value for money in terms of quality and service level (Blome, 2009; Mishra & Tadikamalla, 2006). Sole sourcing in being associated with lower quality due to the imposed lack of incentives for performance improvements from the supplier's side (Larson & Kulchitsky, 1998).

### 3.2.2 Multiple and Dual Sourcing

Multi sourcing is as it insinuates referring to the fulfilment of a buying organization's need for a product or service from more than one supplier at the time. This implies that the total volume for example an article is available from multiple independent suppliers and the volume is divided between more than one of them (Blome, 2009). In an automotive manufacturing context multi sourcing implies that several sets of production tooling needs to be invested in and put to use. When several possible suppliers are identified, approved and qualified to the supplier selection shortlist the decision to use several of them simultaneously means that there needs to be a business case supporting the decision from a financial point of view.

A variant of multiple sourcing is when the fulfilment of a buying organization's need for a product or service is completely satisfied by the use of two suppliers and this is referred to as dual sourcing. Dual sourcing implies that the total volume for example an article is divided between the two suppliers (Blome, 2009). The split of volume in percentage is referred to as the take rate and is used during negotiations between the suppliers and buyers. There are several ways to split up the volume between the two suppliers and the split up strategy depends on the context and desired outcome. Common split ups are 40/40 between the suppliers and a competition about the remaining 20 percent, 80/20 where one of the supplier has the bulk and resourcefulness of economies of scale and the other one is regarded as competing backup supplier with initiative of becoming the bulk supplier if able to compete.

### 3.2.3 Contingency Sourcing

Another variant reciprocal to dual sourcing is contingency sourcing where two suppliers are concerned but only one is sourced from where the other one acts as backup supplier with no volumes appointed (Fang et al., 2013). The backup supplier is allotted volumes only during, disruptions and misadventures at the primary suppliers or during critical capacity hitches.

Contingency sourcing offers the buying organization's opportunity to minimize the risk of disruption (Chopra & Sodhi, 2004). This opportunity requires the backup supplier to be highly responsive in terms of capacity fluctuation and rapid capacity ramp up when needed (Tomlin, 2006) as well as being able to deliver with short lead time otherwise it may be more suitable to apply regular dual sourcing (Fang et al., 2013).

### 3.2.4 Parallel Sourcing

Parallel sourcing can be seen as a variant of single sourcing and refers to the fulfilment of a buying organization's need for a product or service exclusively from a single supplier but having secured that more than one supplier is qualified to supply the product or service (Dubois & Fredriksson, 2008). Having two or more suppliers capable of delivering equal or comparable products or services offers an opportunity to benefit from the single sourcing benefits of close cooperation and low cost while still enjoying the competitive ability of benchmarking and market testing available in dual sourcing (Dubois & Fredriksson, 2008).

### 3.2.5 Single versus Multiple Sourcing

The decision on type of sourcing strategy is difficult since it is firstly contextual where both single and multiple sourcing has its pros and cons depending on the background and situation, and the background and situation can as well certainly change over time. The difficulty of the decision can secondly be associated with its complexity, which means that it is hard to comprehend since it is including many parameters to take into account. Both the single and multiple sourcing strategy can appeal to result in the lowest cost depending on how you analyse the cost structure, but the analysis goes far beyond costs only. The deeper analysis can include factors such as: cost of product, production tooling cost if not owned by the supplier, design and development cost associated to the product, cost of logistics, packaging, customs and cost of capital. Additional areas are quality, delivery performance, supply disruption risk, access to technology and the dependence between buyer and suppliers.

Looking at the cost factors when it comes to choice of sourcing strategy there are two main reasonings recurrently considered in literature. One for and the other one in opposition to single sourcing. The central argument for single sourcing is its cost advantages in behalf of the economies of scale obtained by the consolidation of volume to a single supplier (Blome, 2009; Costantino & Pellegrino, 2010; Mishra & Tadikamalla, 2006; Ramsay & Wilson, 1990; Treleven & Schweikhart, 1988; Zeng, 2000). Using one suppliers will generate less administration (Ramsay & Wilson, 1990) and transactions costs (Blome, 2009), lower ordering and transportation costs (Zeng, 2000) and will generally only require a single set of production tooling. Several authors' points out how using one supplier can help allow more efficient supply chain with less waste (Mishra & Tadikamalla, 2006; Ramsay & Wilson, 1990; Zeng, 2000), with arguments such as smoother production schedules for supplier not risking to get volumes shifted to other competing suppliers and that this should induce more stable demand. This can be questioned since demand fluctuations can be argued to be more linked with buying organizations inventory management and forecast accuracy. There is also a risk of skewed buyer-supplier dependency if the single supplier gains too much power within the supply chain (Chopra & Meindl, 2013), which in turn

opens up for arguments in opposition to single sourcing and instead pro for multi sourcing when it comes to costs. The central argument for multi sourcing is its cost advantages in behalf of the elevated negotiation power enabled by having multiple suppliers that could be interchanged relatively frictionless (Blome, 2009; Costantino & Pellegrino, 2010; Ramsay & Wilson, 1990; Lyon, 2006; Treleven & Schweikhart, 1988; Zeng, 2000). Relying on the above contradicting arguments the cost of the supply chain can be lower applying the single sourcing strategy although the supply chain surplus can be thrown of balance in the favour of the supplier in the case of leverage or competition absence. This implies that the choice of sourcing strategy between single or multiple sourcing, from a cost perspective, to a high degree is determined by the outlook of the competitive landscape.

Quality is in addition to costs also impacting the decision on single and multiple sourcing. An argument in favour for single sourcing is that it is associated with lower product variance as the product originates from one production process only (Mishra & Tadikamalla, 2006; Treleven & Schweikhart; 1988). It could be argued that the impact of the product variance on the delivered product is central but contextual, since it will vary for example a big bended steel sheet and a small piece of moulded plastic. Further arguments in favour for single sourcing are that quality assurance can be less burdensome if the products come from a single source (Blome, 2009) and that more quality benefits can be realized by having closer cooperation and relationships (Mishra & Tadikamalla, 2006; Zeng, 2000) but it could be argued that the relationship between buyer and supplier doesn't have to be directly linked to the chosen sourcing strategy. Arguments in favour for multiple sourcing are that increase in quality can be gained by the competitive pressure between the suppliers and the buyer’s negotiation power (Costantino & Pellegrino, 2010; Lyon, 2006; Ramsay & Wilson, 1990). It also makes it easier to swap suppliers if the chosen one is repeatedly nonconforming (Lyon, 200).

One central argument for multiple sourcing is that the risk of supply disruptions can be mitigated by having more than one supplier, since the not chosen one(s) can act as backup, but Treleven and Schweikhart (1988) argues that consolidating all volume at a single supplier is making the buyer more prioritized and valued in the case a capacity problem for example. A further argument pro single sourcing is that the chance of a disruption actually happening is lower by having fewer supplier. But if one assumes that the other suppliers have enough capacity to cover in case of disruptions the impact is lower when the disruption happens even though the probability is higher (Blome & Henek, 2009). The buyers can be left with limited supply if the supplier's capacity ramp-up time is too long. The management consultancy firm AT Kearny published a report (Bansal & Mathus) stating that it takes one to six months for suppliers to increase capacity with 5-25 % in the automotive industry. This makes the notion of backup suppliers as disruption risk mitigation deceitful as the backup supplier's ability to safeguard lost volumes is rather low (Paquette, 2004). But having to rely on a single supplier might not make the ramp-up time after disruption shorter either (Blome, 2009). In the case of disruption caused by force majeure like incidents like unforeseen strikes, fire, floods and earthquakes being a more valued buyer because of single sourcing will not help (Costantino & Pellegrino, 2010; Ramsay & Wilson, 1990; Zeng, 2000).

Technology need to be considered when deciding upon a sourcing strategy. The main argument for single sourcing is that it leads to increased technology and information sharing and intensifies and improves the product development activities between the buyer and supplier but can nonetheless inhibit the buyer's access to new technology (Treleven & Schweikhart, 1988; Costantino & Pellegrino, 2010; Blome, 2009; Ramsay & Wilson, 1990; Mishra & Tadikamalla, 2006). Single sourcing could increase the supplier's commitment and increase the willingness to investments in facilities, machinery, tooling and technology (Costantino & Pellegrino, 2010). But being tied to a single source of R&D implies reduced flexibility and market intelligence (Ramsay & Wilson, 1990). The main argument for multiple sourcing comes from that competition can generate higher product innovation (Costantino & Pellegrino, 2010). This main argument could be challenged since the volumes in a multi sourcing scenario needs to be split between the suppliers it can lead to a diminished enthusiasm from the supplier to invest in new technology (Blome, 2009).

The notion of dependence is referring to the symmetry and asymmetry in various buyer-supplier relationships and can be favourable when symmetric and mutual and harmful if asymmetric and buyer or supplier dominant (Blome, 2009). The choice of sourcing strategy will be impacted by this dependence and it needs to be taken into consideration.

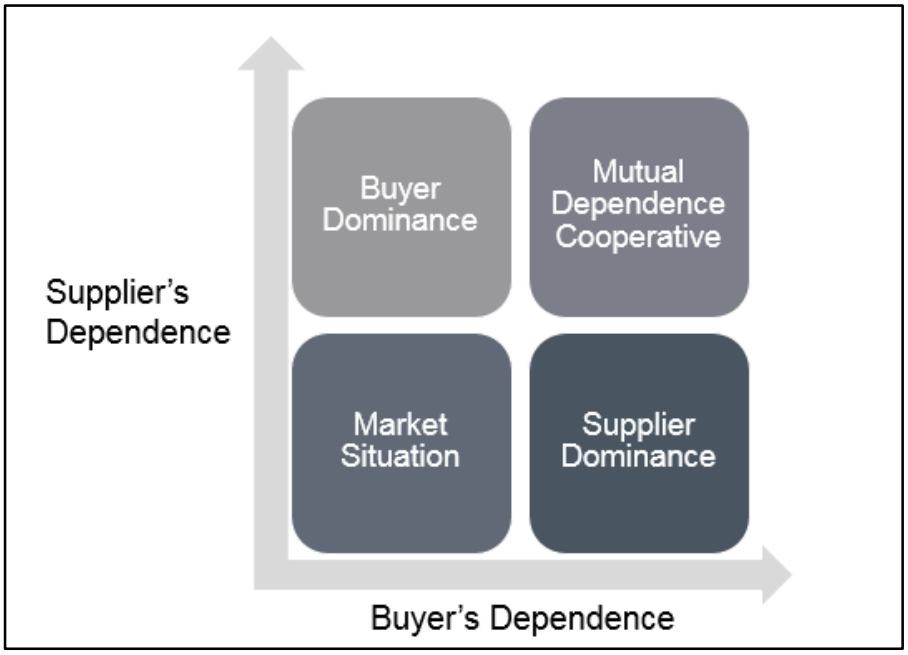


*Figure 3.4. Buyer-supplier dependency (adopted from Blome, 2009).*

The four contrasting buyer-supplier dependency relationships is depicted in figure 3.4 above. If one of the actors has a dominant position it will risks of various kind. In the occurrence of supplier dominance price can be high and performance low (Costantino & Pellegrino, 2010; Zeng, 2000), and in the occurrence of buyer dominance the worst case scenario would be that the buyer might squeeze the supplier into bankruptcy. If the supplier is too dependent on the buyer and do not have sufficient volumes coming from other customers  the supplier might be vulnerable to the

buyers demand volatility, since it will be hard to balance the volatility coming from the buyer (Treleven & Schweikhart, 1988; Ramsay & Wilson, 1990).

### 3.2.6 No sourcing strategy

Apart from the above-mentioned various sourcing strategy, there is another case where, as it was mentioned by Cohen & Young (2006), the company does not have a sourcing strategy, meaning that the sourcing decisions are made on an ad hoc basis. It was further mentioned that (Cohen & Young, 2006) in these organizations, sourcing decisions are taken on a done-off basis in a wide variety of locations around the organization, by many different individuals and groups, there are almost no clear guidelines to make sourcing decisions. The sourcing decisions usually are made not long after the decision on operations, technology, and services strategy. So the consequences of sourcing strategy in these organizations would be that there are no connections in various sourcing decisions.

Organizations are recommended to improve this situation by reordering the sequence of strategy development processes. Cohen & Young (2006) suggested that firms need to answer questions regarding how enterprise will compete in the marketplace, and how to provide value to customers, and how to deliver returns to the shareholders, answers to these questions will form the base for companies to form business vision and strategy which are essential for building an appropriate sourcing strategy.

### 3.2.7 Sourcing strategy summary

Grasping the different alternatives and its implications when it comes to the sourcing strategy have a relevant purpose in the understanding of how to run effective sourcing practices. Since companies in the automotive industry generally requires specialized components, which call for generous production tooling and other investments (Li & Debo, 2009), having excessive number of suppliers would make these investments not feasible. The same goes for the perspective of risk. Chopra and Sodhi (2014) claims that it would be redundant to have more than two suppliers since it comes with enlarged cost whereas the reduction of supply risk is in another ballpark, making multi sourcing a lousy trade off. The study of Fang et al., (2013) is confirming this with a mathematical model revealing that there is an insignificant benefit from having more than two suppliers. Fang et al., (2013) recommends to limits the scope of the sourcing strategy to single, dual or contingent sourcing. Contingent sourcing is as previously mentioned regarded as less meaningful than dual sourcing unless the ramp-up time of the backup supplier is diminished. There is generally a demand for more specialized components in the automotive industry and in this case there could be a need for a close relationship between the buying and the supplying organization, having too many close relationship suppliers could result in high cost and complexity (Newman, 1989, Wynstra et al., 2001). One could conclude that the multi sourcing drawbacks gets aggregated with the addition of each new supplier.

## 3.3 Buyer–supplier relationships

Buyer-supplier relationships and sourcing strategies are highly interlinked and theories are hardly ever making any distinction between them, where single sourcing associate with close and cooperative relationships whereas multiple sourcing is associated with transactional arm lengths relationships (Blome, 2009). But this straight correlation does not always apply since single sourcing relationships can be transactional in cost pressured environments and close cooperation is possible when having several suppliers even though it drives relationships management and cost substantially (Blome, 2009). Although the conventional thought is that single sourcing give rise to closer relationships between the buyer and supplier (Larson & Kulchitsky, 1998). Apart from closer relationships trust is also said to increase by when going for single sourcing (Costantino & Pellegrino, 2010; Mishra & Tadikamalla, 2006; Ramsay & Wilson, 1990). Swift (1995) reckons that trust and cooperation is close to impossible when the number of supplier is high. During the last decade there has been a clear trend among organizations to manoeuvre away from large supplier bases and instead reducing the number of suppliers (Chen & Paulraj, 2004). Supply base reduction implies volume consolidation and hence increased mutual dependency between the concerned actors which requires increased focus and inter-firm coordination (Cai et al., 2010). A properly performed supply base reduction can according to Ogden (2003) derive in benefits such as: increased leverage through volume consolidation, increased access to the technology and innovation of suppliers, decreased supplier management costs and increased quality and supplier responsiveness among else. The opposition to this claim is increased supply chain risk due to increased dependency towards limited amounts of suppliers (Cai et al., 2010; Stamatis, 2012; van Weele, 2014).

## 3.4 Working capital for decision making

Working capital is described as the difference between current assets such as cash, accounts receivables & inventory, and current liabilities. (Hofmann, 2011) The working capital can be considered as current assets which can be financed with interest bearing capital. Hofmann (2011) also states that the possibilities for lowering the working capital are reducing inventory and accounts receivable, or rising current liabilities. Tool decisions on whether to localize leads to different scenarios of working capital. Having localized tool will shorten the lead-time compared with having goods transported from the manufacturing plant, thus reducing the inventory and generate less tied up working capital, although company need to invest on the production tool cost, and having capital tied up on the tool. On the contrary, tool investment is not necessary when having the goods transported from the overseas plant, however, the capital will be tied up in the “pipeline” when the goods are being transported to the destination plant. Additionally, the destination plant will need to build up higher inventory for compensating the unstable factors that potentially will cause supply delays. Hofmann (2011) supported the argument by mentioning that attempts at reducing tie-up capital in the turnover process cause a trade-off between risk and profitability. Hofmann (2011) further mentioned that it means decreasing inventory which ties up capital in the process creates a trade-off between the responsiveness and the cost efficiency.
Positive working capital, when inventory and accounts receivable are greater than accounts payable reduces the risk of loss in production but has a negative effect on profitability due to high

capital commitment, since the financial resources are tied up in the inventory, which otherwise can be re-invested to other projects. (Hofmann, 2011) On the other hand, negative working capital decreases the need for funding but also lead to increased risk of shortages and possible stoppage in production. (Hoffmann, 2011)

Based on the theory mentioned above, the company practically should by a financial management to have low levels of safety buffers to mitigate for short term fluctuations in demand, while at the same time not commit too much financial resources. Decisions on having various tool is a decision of analysing and balancing the trade-off of having shorter lead time, higher responsiveness and more efficient investment. Therefore, it is necessary to understand the financial impact of lead time and flexibility, as these are the parameters for decision making on production tool.

### 3.4.1 Lead time and working capital

Lead Time is the amount of time that elapses between when a process starts and when it is completed (Investopedia, 2014). Little's law provides an equation which takes into consideration to the relating lead time, work-in-process (WIP) and average completion rate (ACR) for any process. The equation follows: *Lead time = WIP (units) / ACR (units per time period).* In the context of this thesis work, it means when the components are sent out from the manufacturing plant, through all the transportation process to arrive at the destination plant. Companies do use forecasting systems to predict the customer needs before the actual demand comes into the system, in order to be prepare for the possible increase on the volume and to build up safety stock for a smooth process. However, Christopher pointed out in the research that forecasting efforts will be always too much or too little inventory. According to Christopher (2008), forecasting error is increased as the lead time gets longer, as it is shown in the figure 3.5 below (Christopher, 2008). Measuring the absolute distance of the two lines, when the lead time goes longer (approaching to the right), the absolute distance increases. The absolute distance is how the deviation of the forecasted value from the "actual" demand, which generates a forecast error.

Lead time affects both revenue and cost. Short lead time is valuable to buyers because it reduces the time to consumption and it is a realization of cash flows. (Lederer, 2009) Lead time is important as it is proportional to the work-in-process (WIP) inventory. Longer lead time make the company suffer from holding finished goods for the next process

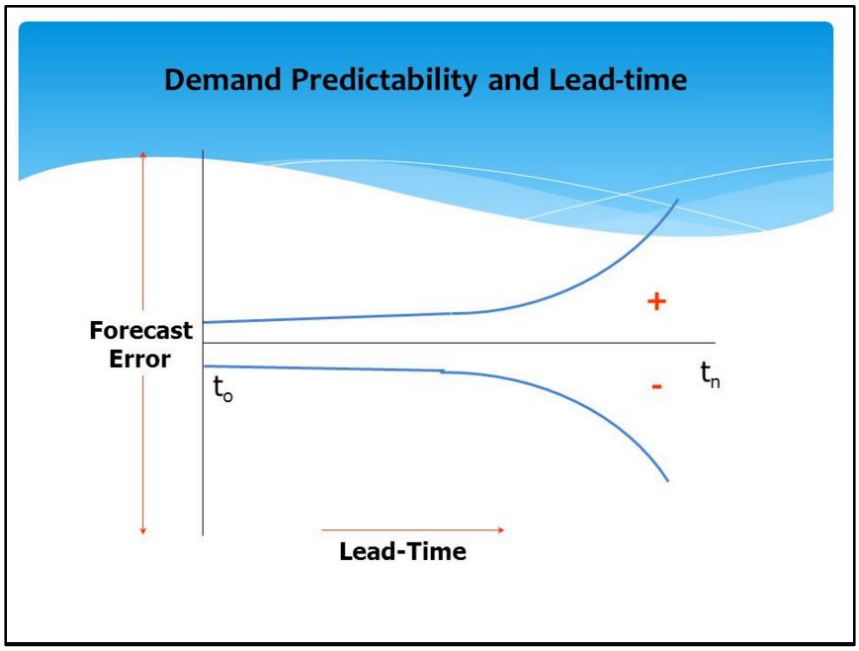


*Figure 3.5. Demand Predictability and Lead time, NG SI LING (2015)*

### 3.4.2 Flexibility and working capital

Production tooling decisions are affected by how much flexibility will the firm to ensure for the production. Flexibility in the context of this study, which takes a material planning and logistics perspective, is defined as how capable the firm can make sure to consistently fulfilling a certain service level towards production. A certain service level need to be ensured in order to assure an adequate level of flexibility towards the production. Organizations make holds safety stock to handle uncertainties from disruptions during lead time and from demand fluctuations and inaccurate forecasts to guarantee enough flexibility in the process. The effect of safety stock on the capital cost as well as the relationship between the safety stock and lead time need to be understood in order to investigate the possibility of making new production tooling decision with consideration to flexibility. David J (2009) defined the function of safety stock in the literature that, it is used primarily to compensate for demand variability that cannot be pre-calculated, he pointed out that effectively calculating the safety stock can make the firm better manage its stock while gaining more value from less inventory. A statistical method calculating safety stock mentioned by David Frederick (2015) will later be utilized in the study as a reference to determine the level of safety stock for each analysed commodity, and thus to understand the financial effect for tooling decision. For further explanation, it is necessary have a brief understanding of the statistical method which was also mentioned by David F., (2015), involved parameters and method are quoted from David, F (2015):

- Demand: The amount of items consumed by customers, usually a random variable.
- Lead time: The total amount of time that spans the period beginning from the date an inventory replenishment order is identified until the date the stock is received.

- Service level: the desired probability of meeting demand during lead time without a stock out. Naturally, when the desired service level is increased, the required safety stock increases as well.
- Forecast error: an estimate of how far actual demand may be from forecast demand.

The formula for calculating the safety stock (SS) is as follows:

$$SS = z_\alpha \times \sqrt{E(L)\sigma_D^2 + (E(D))^2\sigma_L^2}$$

Where,

- $\alpha$ is the service level, and $z_\alpha$ is the service factor which is the inverse distribution function of a standard normal distribution with cumulative probability $\alpha$; The matching service value and service factor are illustrated in the table 3 below.
- $E(L)$ and $\sigma_L$ are the mean and standard deviation of lead time.
- $E(D)$ and $\sigma_D$ are the mean and standard deviation of demand in each unit time period

Table 3. Relation between service level and service factor (David F, 2015)

| Service Level | Service Factor | | Service Level | Service Factor |
|---|---|---|---|---|
| 50.00% | 0 | | 90.00% | 1.28 |
| 55.00% | 0.13 | | 91.00% | 1.34 |
| 60.00% | 0.25 | | 92.00% | 1.41 |
| 65.00% | 0.39 | | 93.00% | 1.48 |
| 70.00% | 0.52 | | 94.00% | 1.55 |
| 75.00% | 0.67 | | 95.00% | 1.64 |
| 80.00% | 0.84 | | 96.00% | 1.75 |
| 81.00% | 0.88 | | 97.00% | 1.88 |
| 82.00% | 0.92 | | 98.00% | 2.05 |
| 83.00% | 0.95 | | 99.00% | 2.33 |
| 84.00% | 0.99 | | 99.50% | 2.58 |
| 85.00% | 1.04 | | 99.60% | 2.65 |
| 86.00% | 1.08 | | 99.70% | 2.75 |
| 87.00% | 1.13 | | 99.80% | 2.88 |
| 88.00% | 1.17 | | 99.90% | 3.09 |
| 89.00% | 1.23 | | 99.99% | 3.72 |

The safety stock formula suggests that as the service factor being a constant number when the service level is set, the longer the distance from supplier, the longer the lead time and higher uncertainties, which results in larger safety stocks and higher capital cost. The figure 3.6 illustrated by David J (2009) below showed the correlation between safety stock and service level, that an increase in service level generally generates higher safety stock requirements, which according to the discussion above, results in a higher working capital tied up.

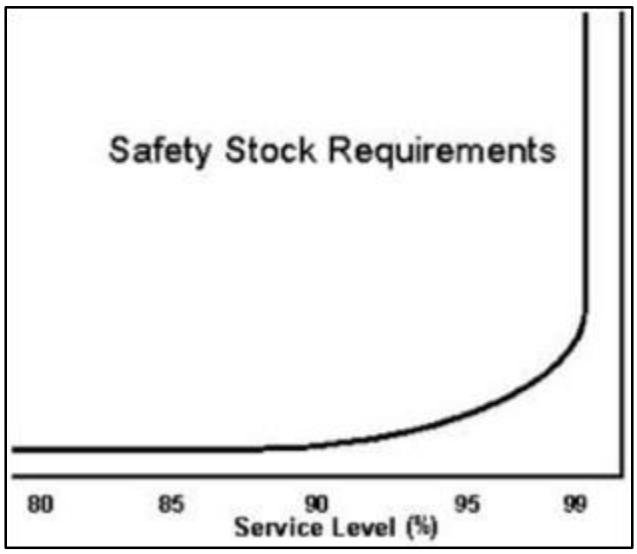


*Figure 3.6. Safety stock and requirements in relation to service level (David J, 2009)*

## 3.5 Landed cost

The study at Volvo Cars have revealed that Landed cost is widely used for calculating costs referred to getting a product to the assigned Volvo Cars manufacturing site, therefore, it is necessary for the researchers to have a sufficient understanding of the landed cost notion in order to guide and improve the analysis stage within the study.

The landed cost, as Young (2009) have defined it, represents the total cost that will be paid for an item, including the product cost, shipment to the destination plant, tax & import duties, receiving in the warehouse, and getting on the shelves ready to consume or sell. A more detailed explanation for each of the mentioned parameters will be elaborated in the following paragraph. Young (2009) have also described that, landed cost embedded within the transactional phase of total cost of ownership. According to Young (2009), there are five modules that are typically involved in a landed cost, each of the five modules will be detailed explained in the following paragraphs in order to create a basic and overall understanding of what are being considered in the Land cost calculation.

1. Product Price. The first parameter involved in the landed cost is fully transactional focused. It is mainly the product price that the buyer and the supplier have agreed upon. Additionally, the payment terms is also a factor that need to be considered including the days allowed for payment of the goods.

2. Transportation cost. The cost of transportation, especially overseas, involve multiple carriers. The cost of multiple carrier depending on the INCOTERMS, abbreviation for International Commercial Terms, which defines the responsibility between buyer and

seller for transportation, duty payment and related commercial terms. (International Chamber of Commerce, ICC, 2010) Young (2009) also mentioned the accessorial charges that may also considered in the landed cost, such as currency fluctuations factors, bunker and other fuel adjustment factors, terminal receiving charges, etc. Additionally, the packaging cost should also be considered depending on the transportation modules selected.

3. Customs duties. The research by Young (2009) revealed that the majority of firms included duties within the landed cost, as well as the transaction fees charged by the customs house broker.

4. Inventory Management. Involving overseas suppliers, means firms need to find ways to compensate for the extra lead time for the long distance. Despite for the transit time, the process of customs clearance may also add significant lead time to the total process. Inventory holding cost, including the cost of funds, loss or damage of the goods need to be taken care of in the calculation. Young (2009) pointed out an active trade off may include changing to a less expensive mode of transportation and incurring additional inventory cost, using a supplier closer to the buyer to reduce time, versus the saving in purchase price, and changing terms whereby the seller owns the goods to port of arrival but may charge a higher piece price as a consequence.

5. Administrative overhead cost. The cost drivers, raised by Young (2009) involving both the sourcing and transactional activities. Transaction related costs may include to engage in bilingual communications, to incur the cost of more frequent communications, and to invest in a range of supplier relationship that include periodic visits. (Bolotova, 2009) The administrative cost also exists in the areas that need for managing the network of additional parties in a global sourcing network, involving the process of contracting, coordination and maintenance of the business relationship.

Figure 3.7 below illustrates an example of a landed cost structure from a supplier in China to a customer warehouse in US.


*Figure 3.7. Landed cost illustration*

## 3.6 Time Adjusted Rate of Return analysis

The research at Volvo Cars have revealed that Time Adjusted Rate of Return (TARR) is widely used as a critical factor for making decision on production tooling investment, therefore, it is necessary for the researchers to have a sufficient understanding of the Time adjusted rate of return in order to guide and improve the analysis stage within the study.

Time adjusted rate of return, also named as internal rate of return (IRR), according to Mendez (2008), is the rate where the investment projects are expected to generate financial return during its lifetime. It is a factor for evaluating whether an investment project can worth for a business case for the benefit of company. Emmanuel (1998) pointed out that TARR is a financial measurement tool used to determine the financial merit of adopting a new process versus retaining the existing process. Mendez (1998) states that IRR or TARR takes into account the time value of money and analyse the investment decision by comparing the IRR to the minimum required rate of return to the company. The profitability is expressed as a percentage with a corresponding payback period expressed in years, it represents the maximum interest rate the company could incur for an investment over the cycle life to break even. (Emmanuel, 1998) The respective TARR and payback are evaluated for investments projects. Emmanuel (1998) demonstrated a short summary where it shows how operating costs for the present system and the proposed new system are calculated and being taking into consideration for the decision making, the factors are listed as follows:

- Investment required to implement the new system.
- Expected useful life of the new equipment (referred as cycle life)
- Present the proposed system operating costs, meaning total per-unit operating costs incurred to process the part under each scenario, taking into consideration on labour, material, overhead etc.
- Warranty costs( if applicable), widely speaking, dealer incurred repair costs with material and labour included and charged back to the company

- Depreciation. Referring to the total investment less residual value resulting in the net value allocated over operating cycle life.
- Maintenance, estimated upkeep and repairs on equipment spread over the cycle life.
- In general, The TARR calculation is relevant when the capital cost is an appreciable portion of the cost to test one part or component.

A cash flow analysis is carried out when the above-mentioned factors that have been calculated. In order to have a general understanding to the terminology, a hypothetical example is presented in the table 4 below.

Table 4. Example of TARR analysis (Emmanuel (1998)

**Testing compared to non-testing***

| Testing cash flow over/(under) non-testing | Cash flow | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production life cycle ($000) | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Investment | $(50) | $ | $ | $ | $ | $ | $ | $ | $ | $ | $ |
| Depreciation | | (5) | (5) | (5) | (5) | (5) | (5) | (5) | (5) | (5) | (5) |
| Residual value | | | | | | | | | | | 10 |
| Operating cost | | (3) | (3) | (3) | (3) | (3) | (3) | (3) | (3) | (3) | (3) |
| Warranty cost | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Maintenance | | | (1) | | (1) | | (1) | | (1) | | (1) |
| Profit before tax | $(50) | $ 12 | $ 11 | $ 12 | $ 11 | $ 12 | $ 11 | $ 12 | $ 11 | $ 12 | $ 21 |
| After tax cash flow (incl. dep'n. add-back) | (50) | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 16 |
| Cumulative cash flow | | (39) | (28) | (17) | (6) | 5 | 16 | 27 | 38 | 49 | 65 |

**TARR** = 18%
**Project payback period** = 4.5 years

*Assumptions:
- **Investment** – $50,000 for test equipment
- **Operating cost** – Testing is $3,000 more annually than non-testing
- **Life cycle** – 10 years
- **Residual value** – $10,000 salvage value after 10 years
- **Warranty** – $20,000 annual savings with testing
- **Maintenance** – $1,000 every second year
- **Depreciation** – 10 year straight line to zero with the Residual Value being an uncertain revenue.

Practically, the minimum required rate of return is decided by the top management team and it is usually set to equal to the cost of capital of the company. And it is also the case for this thesis work, that the minimum required rate of return is the same as cost of capital at Volvo Cars. By theory, the investment project, in this case, the production tooling investment to different car projects are considered worthy and acceptable if the TARR calculation shows it is greater than or equal to the cost of capital at Volvo Cars, otherwise, the investment proposal will be rejected and the project team are required to consider alternatives for investment, although the theory from Emmanuel (1998) suggested that ordinarily, there is a lower bound on profitability and an upper bound on payback period set by company policy, and if the proposed system is less profitable

and/or requires a long payback period to payback the capital, then the project proposal will not be considered.

Even though TARR is a reasonable method for quantifying a proposed investment the TARR is recommended to be supplemented with other information. Examples of such information can be how the investment can increase the capacity of a bottleneck operation or how the investment can reduce the working capital or how it can resolve a legal requirement imposed by local government ("What is the time-adjusted rate of return? - AccountingTools", 2016).

## 3.7 Regionalized Supply Chains

It is currently common to notice that global companies are developing supply strategies aligned to a setup around the three mega regions US, EMEA and APAC. Lee & O'Marah (2013) points out that companies such as Nokia operates with a balanced manufacturing footprint with production capacity in each mega regions and enables efficient serving to all global markets with a degree of regional proximity that reduces lead times and communication problems. Another example is the hi-tech manufacturer Cisco Systems which has regionalised its supply chain to enable improved pace with clients occupying all regions in comparable volumes. Lee & O'Marah (2013) also say that many automotive and packaged consumer goods industry actors are increasingly structuring the supply and manufacturing footprint this way. One reason is that the actors want to operate as locals to limit exchange rate risk (Lee & O'Marah, 2013).

### 3.7.1 Shorter global value chains

The expression "shortening global value chains", coined in a quote from Douglas Lippoldt, Senior Trade Economist at HSBC Holdings. It is accurately describing a current phenomenon where supply chain executives have, for at least the past five years, been reacting to rising risk levels, higher labour costs and a need to be closer to customers by regionalising their supply networks (Lee & O'Marah, 2013). The faddy concept of reshoring, which is very trendy in US, further infuses the shortening of global value chains politically. It is however more about progressively localized supply chain designs with the purpose of reducing risks and total landed cost as well as to exploit advantages in rapid technological improvement within robotics, additive manufacturing and the internet of things (IoT) to enable more customised product offerings finished closer to the point of sale (Lee & O'Marah, 2013). Globalization may once have been highly associated with low-cost country sourcing but is currently shifting toward and referring to the leveraging of valuable intellectual property like brands, designs and formulations with local or regional supply chains. Global companies are recognizing the benefits of manufacturing, sourcing and distributing goods close to their end-use markets (Lee & O'Marah, 2013).

### 3.7.2 Localise to thrive

Lee & O'Marah (2013) are sending a simple message to the supply chain strategists and the messages says use emerging technologies of customer centricity to improve the understanding of demand and utilize the tools of smart manufacturing to increase the precision to make exactly what customers want. With today's technology companies can know their customers intimately

and given the tools of collaborative robots, 3D printing and flexible machinery, why not produce products when and where they are needed?

Lee & O'Marah's report (2013) "Manufacturing footprints: Getting to plant X" they are calling attention to where manufacturing strategies will make a difference when balancing scale at low cost with agility and flexibility. The direction of improvement is depicted in the figure 3.8 below. The figure shows that improvements must be aligned in the direction of the efficient frontier getting the organization's producing plants toward something Lee & O'Marah (2013) calls "Plant X" which is a plant both efficient in terms of cost and process innovation as well as agile in terms of customer service and product flexibility.

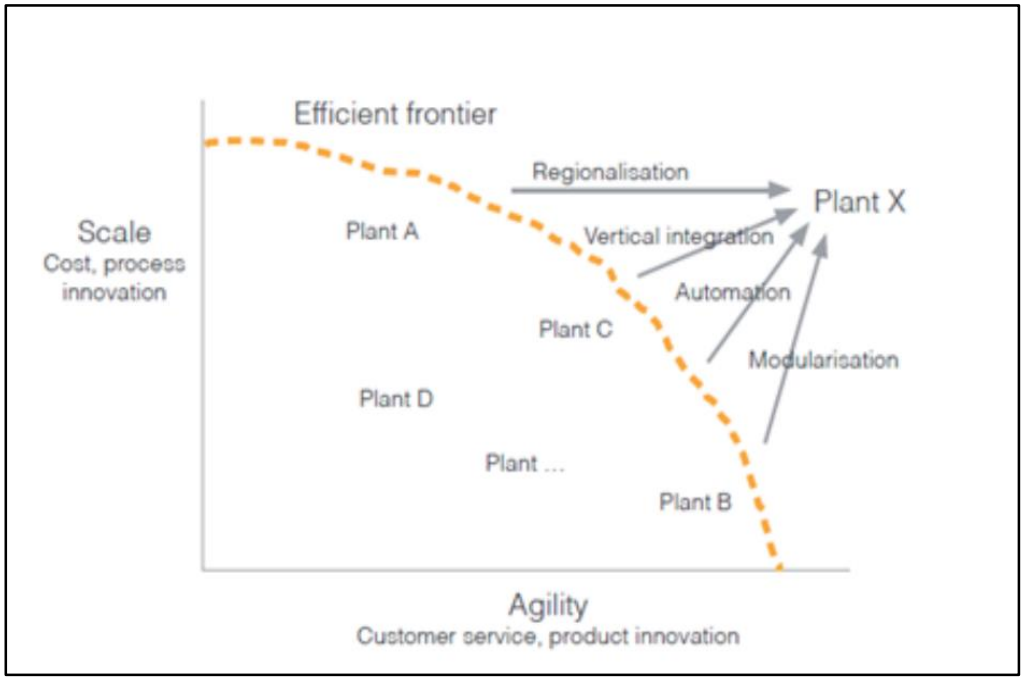


*Figure 3.8. Manufacturing footprints: Getting to plant X (adopted from Lee & O'Marah, 2013)*

# 4. EMPIRICAL DATA

*This chapter describes the empirical data which forms one of the base of the coming analysis and discussion chapters, as it is important for the readers to understand the reality and the background of the study to see in which context the theory has been applied. The chapter starts with an introduction to the Volvo Product Development System to illustrate the project development stages, so the readers get a holistic view of where the purchasing function is placed at different car projects. The chapter then zooms in to general information about purchasing to bring a close picture of purchasing at Volvo Cars where the purchasing process will be described. The sub process for purchasing have been detailed explained in the chapter, including the sourcing process, ordering process for material and production tooling, and the quality assurance process. In order to get an understanding of sourcing process and understand where and how the tooling decision have been involved in the sourcing process, the chapter included an introduction of the sourcing template and production tooling.*

*Referring back to the core analysis of the project, the insight of the five commodities will be further explained with the product property, production tooling status and other aspects where it may applies only to a specific commodity but it is of great importance for the reader to understand. Having understood the commodities and the current situation, the extra parameters which are planning to be added to the existing sourcing model will be introduced.*

## 4.1 Volvo Product Development System

All the activities at purchasing organization is a part of the Volvo Product Development System (VPDS). The purchasing activities are initiated by the previous activity in the VPDS. The VPDS is a cross functional logic to develop vehicles in time with the right quality, right cost and in good time. VPDS describes the logic of how the components are integrated and synchronized the process of car project at Volvo Cars. It demonstrates an overview of how all the functionalities, including Product Strategy & Vehicle Line Management, Design, Research & Development, Quality and Customer Satisfaction, Purchasing, Suppliers, Manufacturing, and Marketing Sales & Customer Service are integrated in the process and critical gateways in the project. As it is illustrates in the process map below, VPDS defines the development process of a vehicle from concept phase to industrialization. However, to give a holistic understanding, a brief introduction of other functionalities will be provided (see figure 4.1 below).

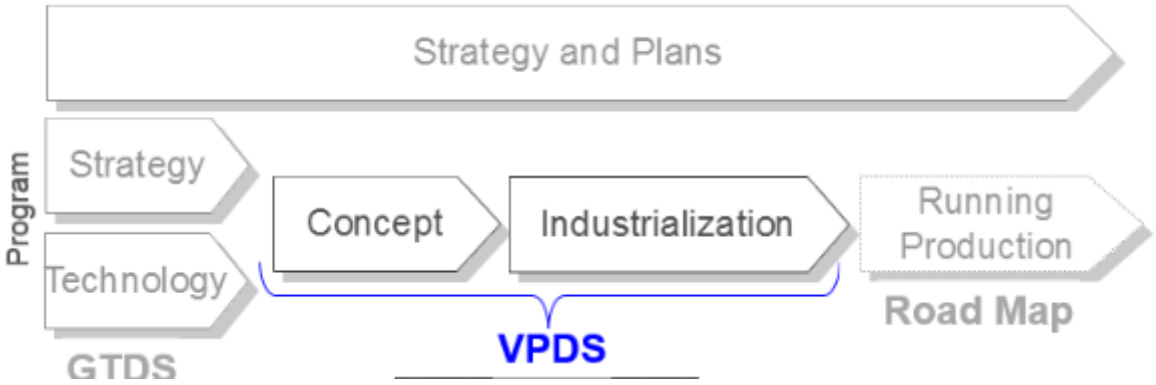


*Figure 4.1. Volvo Cars Product Development System (Volvo cars Intranet, 2014)*

**Strategy stage:** To investigate and decide which type of cars should Volvo Cars to have to meet the market demand.
**Technology stage:** To develop new technologies, and the new technology should be developed according to Global Technology Develop System (GTDS), and technologies that developed here will be implemented to the car projects.
**Concept Stage:** Get all the available technologies at hand, together with the information from the marketing side, to make a total balance on the car project in order to decide which technology Volvo Cars should have in the car projects.
**Industrialization stage:** Continuing with the achievement that made in the concept stage, such as, what have been digitally constructed, carry out test and prepare an introduction for the car to the market, to make sure the car project is profitable and begin to manufacture it.
**Running Production stage:** Here the mass production starts up, beginning of the production is not the end of the project, since there will be constant changes on the vehicle to improve the performance in different aspects, product changing process is going parallel with the running production.

In summary, the process overview and the connection between the units involved in the Volvo Product Development cycle can be described as in the figure 4.2 below. The figure depicts the cyclic connection between the departments in the product development process where purchasing has a deliberate role.


*Figure 4.2. The product development cycle (Volvo cars Intranet, 2014)*

## 4.2 General information on Purchasing Organization

Volvo Cars' Purchasing function is called Volvo Cars Direct Purchasing and Program Purchasing (DM&PP) and is responsible for the supply of the right materials and services to the right cost, quality, quantity, technology and on time delivery, which is essential for the company being able to run smoothly and streamlined. The purchasing function is ultimately responsible for all purchase and the selection of suppliers and the relationship with these suppliers. Volvo Cars' purchasing function employs around 500 people globally. The annual cost split of purchasing at Volvo Cars is 81 BSEK for direct material and 36 BSEK for indirect purchasing.

Volvo Cars' Research & Development function is spending 45% of its budget on External development, Consultants and test material. The multiple engineering centres deteriorates scale advantages in single point of contacts for supplier and Volvo Cars Engineering and Purchasing functions. All the following empirical data is within the scope of the DM&PP where this study has been executed.

## 4.3 Purchasing role in VPDS

As it has been described in the previous paragraph, purchasing function plays an important role in the Volvo Product Development System, involving from the Concept Phase to the final Industrialisation Phase. The industrial phase is further divided into two sub stages, which are industrialisation phase 1 and industrialisation phase 2.

The main responsibility of the purchasing organization in the concept phase is to investigate potential suppliers on the market, choose the interested suppliers can begin to gather information from the prospective suppliers. The information gathering process starts with sending out an RFI, short for Request For Information. RFI is a standard business process whose purpose is to collect written information from the potential suppliers, the information usually covering a general

company description, product range, and yearly turn over, customer base, certifications, and capabilities etc. As it was defined within Volvo Cars, RFI is often used as a solicitation send to a broad base of potential suppliers for the purpose of conditioning supplier's minds, developing strategy, building a database, and preparing for further information requesting documents, such as Request for Proposal (RFP), Request For Quotation (RFQ).

The sourcing process and agreement are signed during the concept and industrialisation 1 stage, the suppliers for the specific car project should be appointed in the end of the industrialisation 1 stage with a written Commercial Program & Pricing Agreement (CPPA). Parts and tooling orders should are being carried out during Industrialisation 1 and Industrialisation 2 phases. After the orders are sent to the suppliers, the purchasing organisation will be responsible for a quality follow-up check together with the engineering function to insure that the parts and tooling ordered previously are meeting the agreed standard. The process is named Product Quality Assurance, and it is divided into four stages of Production Part Approval Process (PPAP), PPAP 0, PPAP 1, PPAP2, and PPAP3, a detailed description of each stage will be demonstrated in the coming sections.

## 4.4 Purchasing Process Description

The overview of purchasing process at Volvo cars can be described in the process map below, starting from a sourcing needs resulted from the strategy and concept point of view, through the process of sourcing, ordering, and quality assurance to an approved product. Each of these key phases in the purchasing organization will be introduced in the coming paragraphs in order to give a holistic understanding of the purchasing process, more importantly, these process information serves as ground information for this improvement project (see figure 4.3 below).

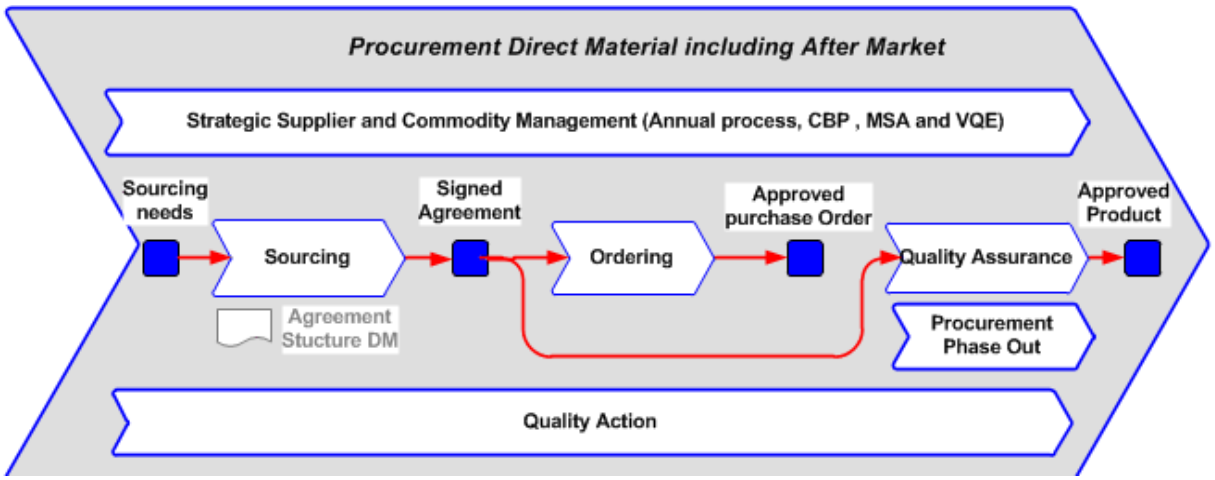


*Figure 4.3. The purchasing process at Volvo Cars (Volvo cars Intranet, 2014)*

### 4.4.1 Sourcing Process

The sourcing process starts when a sourcing need is confirmed, it starts with a sourcing planning, continuing steps are sourcing approach, sourcing quotation, sourcing consensus and signing agreement. The progress is presented and approved at various levels represented in gate meetings at the DM&PP Department. The gates are in escalating order the Global Council, the Supplier Choice Meeting and the Supplier Choice Council (see figure 4.4 below).

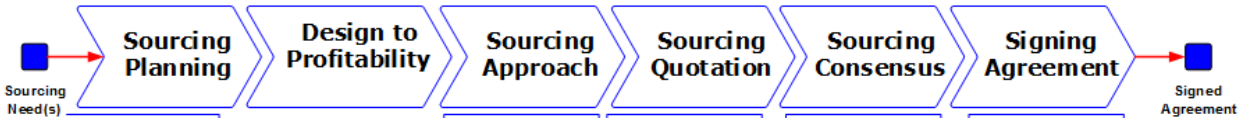


*Figure 4.4. The Sourcing process (Volvo cars Intranet, 2014)*

#### Sourcing planning

The purpose of the sourcing planning is to establish and agree on a plan for purchasing sourcing activities, the input of the sourcing planning is a sourcing needs and the process output is a decided sourcing plan. The Purchasing Program Manager and R&D concept leaders together with the Purchasing Program Manager will collaboratively decide on a sourcing plan and schedule time for the sourcing decisions which will secure the sourcing of commodities according to the program timing milestones. Based on the sourcing plan, the business analysts schedules the time for the gate meetings in the next processes; the Sourcing Approach Process and the Sourcing Consensus Process.

#### Sourcing Approach

Having agreed on the sourcing planning, the buyer identifies potential suppliers and methodology that is in line with the approved commodity strategy. The commodity buyer and the technical manager together with a program manager from Supplier Quality Management (SQM) view different methodologies and the possible buyers. The buyer recommend his approach on the Supplier Choice Meeting where it is approved or disapproved. The sourcing approach process input is a decided sourcing plan and the process output should be a decided sourcing approach, the sourcing approach process is for the commodity buyer be able to send out RFQ to the potential suppliers.

#### Sourcing Quotation

After having necessary approval from the sourcing approach, the buyer shall issue the RFQ package to the potential suppliers. Prior sending RFQ packages, the buyer need to secure that the confidentiality agreement is signed by supplier, in the case of not agree to the agreement, the supplier will be disqualified. After received sourcing approach approval, the buyer shall collect prerequisites and necessary data to execute the competitive quotation activity. The necessary data includes: A generic RFQ package updated with program specific information by the purchasing program manager; A released Engineering Statement of Work (ESOW) for RFQ, as the fact that ESOW is a contractual document and the release of a new issue takes place when all parties agree; Quality, Cost, Weight and Functional targets must be in balance with what is

described in the ESOW, from component up to complete vehicle. After all these documents are ready, the buyer sends out the RFQ package to selected suppliers.
After the RFQ package is sent to the suppliers, the buyer informs cost estimating (CE) when RFQ is released and send a copy of the RFQ to CE. The buyer and the system responsible need to check whether the suppliers have understood the RFQ and both the supplier and Volvo Cars agrees the package is complete for submitting a quotation. The RFQ presentation shall be done by the supplier approximately two weeks after received quotation. The process deliverable is successfully completed when a quotation is received from the suppliers.

#### Sourcing Consensus

The process input is a quotation and the process output is an agreement package ready for signature. Having all suppliers invited to quote and after quotation presentations, the buyer performs the negotiation with the recommended supplier chosen from the result of the quotations. The support is required from the cross functional teams including cost estimating representatives. When the result of the negotiation is within target, the buyer updates the necessary sourcing consensus document. The buyer should make sure that sourcing consensus recommendation is communicated and aligned with stakeholders such as R&D, SQM and concerned management. The sourcing consensus documentation should be filed on Wednesday one week before the Supplier Choice Meeting (SCM) after the document is agreed. The file should be presented on the SCM meeting. A resourcing is needed if the supplier recommendation is not approved from the SCM, otherwise, the Purchasing Program Manager will update the relevant document with the decision. The agreement Package is then to be signed.

#### Signing Agreement

The buyer review the prepared agreement package together with the product buyer and system responsible (SA) and then presents it to the supplier.
If the supplier accepts the agreement both parties (buyer and supplier representative) sign the agreement, and the purchasing project leader should be informed. If the supplier does not accept the agreement, the commodity buyer escalates to the group manager following an internal escalation process. The process deliverable is successfully completed when an agreement package is signed and stored.

### 4.4.2 Ordering Process

The ordering process at Volvo Cars are categorized into three different categories, namely material order, and tool order. The ordering process will be detailed explained from these three aspects. The application used for ordering activities is called SI plus.

#### Material order

The material order are including the blank order for the running productions as well as the blank order for the pre-series vehicles. A buyer will be allocated to the new part and flagged as “Master buyer” for distribution of requisition in SI plus. The new requisition is created according to the information from the forecasted volumes and volumes existing parts per plant. Decisions of where the part should be located will be made prior to the material ordering. The buyer of the correct

purchasing organization location will be appointed to the part and responsible for create and publish the order, and send out the order to the supplier after the order has been approved by the approval chain.

#### Tool order

The tool order at Volvo Cars is further divided into production tool and prototype tool. The purpose is to have a common and effective procedure for how to handle tool ordering for production material at external suppliers, purchasing of the tool can happen at the following occasions:

- New programs and face lift on the current car models
- Re-sourcing
- Capacity increase
- Replacement of tools due to excessive wear
- Running changes on the existing parts and tools

Prototype tool is manufactured for making prototype parts, the tooling cost for the prototype is lower than the ordinary tool, and sometimes called “soft tools”. Prototype tool is sometimes needed for further R&D investigation on the technical issues before issuing the order for the actual tool, in order to save on too much technical changes on the ordinary tool and to be time-effective.

### 4.4.3 Quality Assurance Process

The Quality Assurance Process is carried out by another organization at Volvo Cars, the Supplier Quality Management (SQM) which serves as a supportive function to the purchasing organization. SQM belongs to the Supplier Quality & Logistics (SQL) organisation. The SQM team is responsible for the quality assurance from the Annual assessment to the sourcing process, Program process, and running production. The quality assurance process where purchasing is involved is called Production Part Approval Process (PPAP). Other activities involved in quality assurance process will not be introduced in this thesis, as it is the main function of another organization and out of the project scope.

#### Production Part Approval Process

The production Part Approval Process aims at providing part approval status in product projects, to release serial deliveries and for payment of Volvo Car owned tooling. It defines generic requirements for production part approval, to determine if all customer engineering design record and specification requirements are properly understood by the organization and that the manufacturing process has the potential to produce product consistently meeting these requirements during an actual production run at the quoted production rate. In order to improve launch performance, Production Part Approval Process (PPAP) is structured into a phased approach that will require an organization to demonstrate manufacturing capability, product quality and production capacity prior to job 1 of the mass production. The PPAP phase will provide Volvo Cars and the Supplier with an improved understanding of Supplier Manufacturing process and part readiness. The PPAP is phased as PPAP0, PPAP1, PPAP2, and PPAP3. A detailed explanation of each phase are as follows:

- PPAP 0: 'Run-at- Rate: To confirm that all production input requirements are available and understood, and can support a limited production run. To provide an early indicator that the design of the process and tools has the potential to produce at rate the required number of acceptable parts as determined by the pre-launch control plan.
- PPAP 1: Quality Verification utilizes parts produced during the PPAP 0. To confirm all customer design record and specification requirements are properly understood by the supplier. To provide an early indicator that the design of the process and tooling has the potential to produce product consistently meeting these requirements during an actual production run at the quoted production rate by operating a minimum of the one selected production stream.
- PPAP 2: Production Verification: To confirm all customer engineering design record and specification requirements are properly understood by the supplier and that all production streams have the potential to produce product consistently meeting these requirements during an actual production run at the quoted production rate.
- PPAP 3: Capacity Verification: Verify the supplier's production system can support customer declared volume requirements while meeting phase 2 requirements.

## 4.5 The Sourcing Template

The above mentioned sourcing process at Volvo Cars is guided by a sourcing document with sections. It is an Excel document that have been divided into Sourcing plan, Sourcing Approach, Sourcing consensus information, sourcing summary and recommendation, and control model information. The sourcing template will be explained section by section below. Product buyers are obligated to use this template for the new sourcing, functioning as a working document for comparing and evaluating the quoting suppliers, the document is not supposed to be presented at the administrative meetings, but the result of the working document, demonstrated as PowerPoints with a standard format, should be used for presentation document to the management for the administration purpose. Each of these five key sourcing steps in the sourcing template will be elaborated in the coming paragraphs. Understanding for the sourcing template is significant for having an understanding for the existing sourcing decisions and hence also the production tooling decisions, whether it should be single, doubled or tripled, as different cost parameters are being calculated and summarized in the sourcing template for making production tooling decisions.

### Section I, Sourcing plan

Souring plan is the beginning of the template where basic sourcing information is filled in, such as: the responsible buyer, function of the buyer, the date that RFQ have been sent out, date RFQ should be answered by the supplier, and from which version of the Engineering document the RFQ is referring to.

During the sourcing process, when the buyer is having more and more clear of the time plan by working together with the suppliers and cross functional internally, the areas such as Sourcing Agreement date (SA), SA piece price, Commercial Product Agreement (CPA), CPA signed piece price should also be filled in.

Sourcing plan section can be used as a time management tool for the whole sourcing process, and product buyer are required to having the time control while at the same time compare the sourcing timing with the project time plan, so the milestones of the project are met.

## Section II, Sourcing Approach

The first subsection in Sourcing Approach is the Program overview, where detailed information of the vehicle program is presented, such as:

- Part and general information and Start of production (SOP)
- Program Affordable
- Volume over life cycle
- Local cost estimates on part price and tooling
- List of potential suppliers, rationale and the different approvals (SEM; SQM approval etc.)
- Total Yearly volume (defined by the program purchasing). Specifying the pieces per car, take rate percentage, and the agreed volume.

The second part of the sourcing approach is to demonstrate the suppliers and rationale, to get an overview of the suppliers that Volvo Cars are approaching and what is the current status of their suppliers, e.g. if the suppliers can be internally audited by the Supplier Quality Management (SQM) team, is there any open warranty claims on the chosen supplier etc.

## Section III, Sourcing Consensus

The first part in the sourcing consensus is for the cost comparison between the quoting suppliers, so buyers and management have a clear overall control of the answers on RFQ for the specific sourcing project. The compared parameters are cost-focused, the following items are being compared between different suppliers:

- Cost calculations in local currency, incl. Raw material, process cost, and process overhead.
- Full cost of the produced parts.
- Sales price of the suppliers where the cost for Design and Development cost (D&D), Tooling cost, Transportation cost etc. are being considered.
- Landed cost, including Volvo Cars unique tooling, equipment checking, tooling at start of production and tooling in running production
- Total lifetime tool cost
- Total D&D cost

The second part in the sourcing consensus is for prototype multiples and leverage. Since there are different stages of the car project, and each stage of the project requires a certain amount of test vehicles and this should the supplier support as well, thus have been taken consideration in the sourcing consensus part of the sourcing template.

The third part of the sourcing consensus is for the total cost comparison between quoting suppliers, where total spend on sourced programs is demonstrated, taken into consideration of the exchange rate, life time volume, and other accumulated cost.

The fourth part is to make cost comparison horizontally, by comparing new sourcing and current cars and prices, so the sourcing is also compared with the existing suppliers, thus to identify leverage on the current business. Some of the commodities need to make this analysis as a lot of part in such commodity are carry overs to other car programs.

## Section IV, Summary and recommendation

Summary and recommendation in the sourcing template is where the supplier choice is summarized and presented. Based on the calculation from Sourcing consensus and previous sections in the sourcing template, conclusions regarding the recommended supplier, cost summary and cross-functional alignment are presented in this part of the template.

In the cost summary, the information concerning the financial aspect will be controlled, the presented information in the sourcing template contains  the final status on the business offer, does the total package lies within the total program budget, how much does it differs from the reference price. Based on the information above, the management team will have an overall view of the sourcing status and therefore making the decision to begin the cooperation with the chosen supplier or to make an initiative for a new round of sourcing.

In the cross-functional alignment, departments involved in the sourcing process need to come in an agreement and be aligned

- Program management need to have a total control of the sourcing so it is within the budget,
- The SQM team need to approve the supplier from the hardware and software perspective, regarding the certificate, facilities, etc.
- Cost estimation should identify the cost gap and product buyers need to close the gap or be even better than the estimation to get the deal approved.
- Engineering (R&D) team should approve the supplier from the technical point of view, so the designs and solutions are technically feasible.
- The MP&L department should be approved for the packaging instructions and means of transportation by the supplier so there will not be any issues regarding the raw material supply and the later transportation to the plant.
- After market should also be involved in the early stage to be well prepared for the maintenance parts, since the part price usually differs from the mass production due to the low volume, so there should be an alignment between the purchasing for running production and purchasing for aftermarket. So there is a sufficient level of control on the product during the life cycle span.

## 4.6 Production Tooling

Production tooling in the context of this study refers to the facilities and production equipment that is required to manufacture automobile components. In some cases, the production tooling not only refers to the production equipment, but also including the control fixtures for the quality assurance. Production have different categories, depend on the manufacturing purpose of the tool, it can be categorized das cutting tools, dies, fixtures, gauges, or moulds of a specialized nature which, unless significantly modified, are confined to produce a specific component or family of components. A typical type of the production tooling is illustrated in the figure 4.5 below.

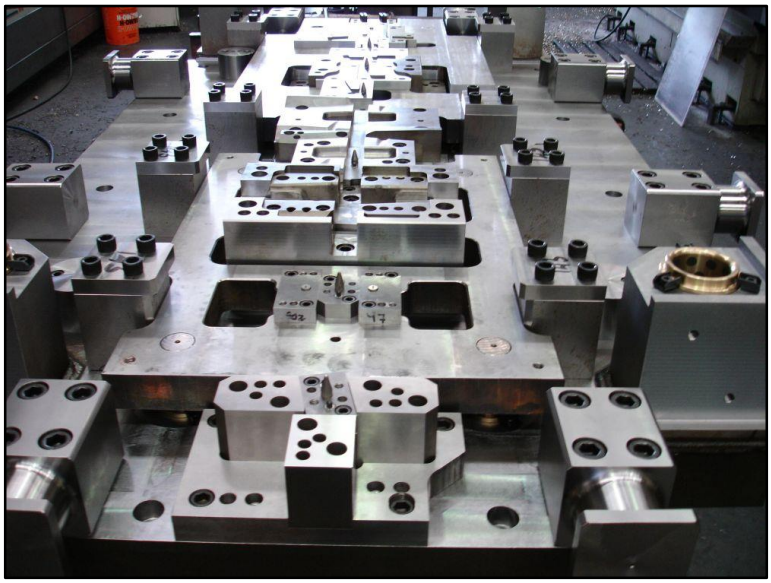

*Figure 4.5. Picture illustrating a set of production tooling. (HLH prototypes, company website)*

By analysing the total cost of producing a car component, the production tooling is one of the most significant financial constraint against multiple sourcing. The value of the production tooling is depending on the complexity of the commodity, often in the 10-100 MSEK category. Another side of the serious concerns on the production tooling lies in the fact that, the time constraints need also be taken into consideration were the sometimes long lead time of producing a set of production tooling can be out of the time frame of a car project. Volvo Cars have a present policy that the production tooling should be owned by Volvo Cars but is produced by the component's suppliers. Supplier are naturally driving for a balance of an optimized tooling cost, tooling quality and tooling timing. The tooling cost are in a significant variance depending on the workload of the tool makers. In some cases, a delay have to be accepted and well sorted in order not to have serious delays to the whole project. During the study, the researchers have experience the situation where the lead time to produce the production tooling cannot be met by the suppliers due to the high and work load of the production tooling manufacturer supplying the suppliers, and Volvo Cars in this case need to take extra negotiation with the supplier to come into a solution to minimize the effect of delay. Making a localized production tool decision means the project

management teams need not only taking the consideration of the effect on the cost, but also to supervise the effect on the project time lines.

## 4.7 The five commodities

The five targeted commodities which the study is based on will be introduced in this chapter. Each of the following sections will start with the rationale for choosing the commodity, continued with the general commodity introduction with current sourcing decisions and production tooling situations of the commodity. Additionally, there will also contain information specific to each of the commodity as a preparation for the subsequent analysis chapter.

### Commodity 1: Steering Wheel

Steering wheels is a complex product with the features of being high value, quality sensitive, and labour intensive. There are different steering wheels for different car models and a lot of variants depending on the version of the car model and the steering wheel consist of many components. This study is going to focus on the steering wheel excluding the airbag for the car models in the CMA platform. The CMA steering wheel have currently three suppliers on the short list, however there have been a serious quality claims on one of the suppliers airbags so Volvo Cars does not consider that supplier as a candidate in the sourcing process.

At present, the CMA steering wheels are sourced from Europe for the final assembly lines of Volvo Cars in Belgium. Additionally with the raising demand from the Chinese market as well as the launch of the new car models in the CMA platform to serve Asian market, the purchasing have decided to localize the suppliers in china hence have localized production tooling, for the Chinese final assembly plant as well. Another factor for localizing the steering wheel is that the product itself is very sensitive to any type of scratch that are likely to take place during the long and unforeseeable transportation process. Any scratch to the product is not tolerated as the product is very visible to the customers, and is directly connected to product reputation as well as customer satisfaction.

The labour intensive feature on the steering wheel makes the commodity suitable to be produced in relatively low cost countries. The steering wheels today are manufactured in European low cost countries, and is fulfilling the demand from the European Gent Factory. The demand from China is fulfilled from supply coming from China. In addition to the European and Chinese market, Volvo Cars is also working on the sourcing and hence the production tooling decisions for the coming US final assembly plant, which is under construction at present. However, it is a not widely accepted by the management that the R&D department stated the lack of resource to evaluate and bring in new US suppliers. The project team is processing the sourcing work with the global suppliers who are familiar with the Volvo way of working and also have base in US, since this sourcing is ongoing there were no official data on it and this study does not cover the American volumes.

The sourcing scenarios for the CMA steering wheels that will be analysed in this study are:

- Localized production tooling in Europe and ship Chinese volumes to China
- Localize another set of production tooling in China for Chinese volumes

Localization within the Europe is not an interesting case for the study as the production was first initiated in Europe and there is not much to be considered. However, it is worth studying the case whether to have localized production tooling in China or if it is more profitable to ship the components from Europe to China.

## Commodity 2: Seats

The second commodity that have been considered in this study is the seat. The seat is a representative commodity to be analysed for production tooling decision making since it is a complex commodity with a large amount of sub-components included, and the sub-components are supplied by three levels of suppliers, tier one, tier two and tier three. The number of variants and high level of customization further drives the complexity. Due to the complexity of the seat, the inventory is managed by a Just-In-Sequence (JIS) flow. JIS is a variant of Just-In-Time (JIT) enabling the supply chain to deliver the components to Volvo Cars' final assembly plant a couple of hours ahead of consumption in the right sequence. The first tier supplier is located in near distance to the Volvo Cars final assembly plants. The supplier setup and the three supplier tiers for the seat is illustrated in the tree-chart in figure 4.6 below:

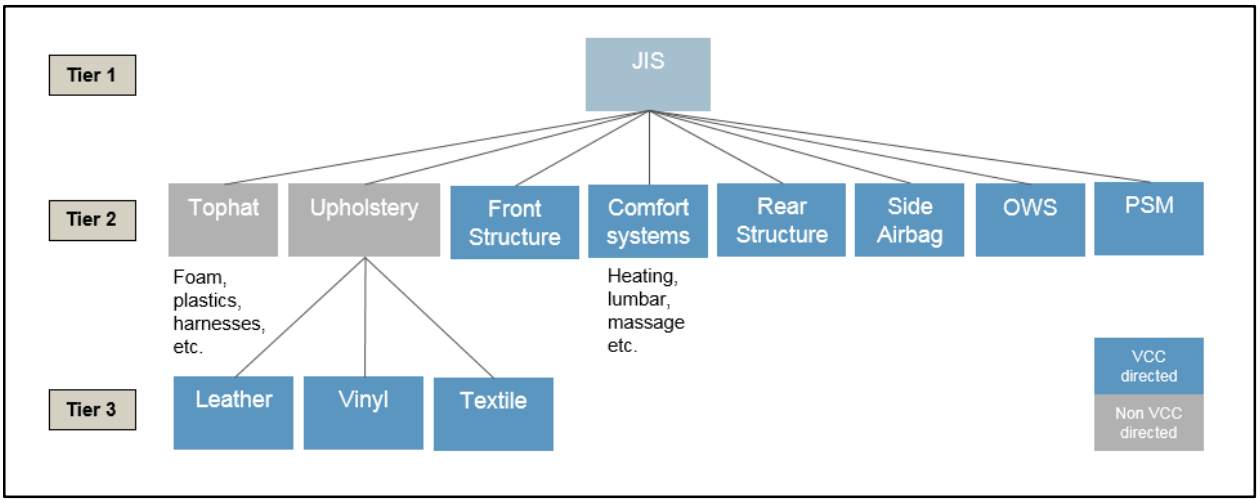


*Figure 4.6. The seats product tree.*

As seen in figure 4.6, there are several component systems involved in the seat commodity and the customers have the possibility to modify the seats up to 20 000 different combinations. Within all the subcomponents, body structure have a relatively high production tool cost despite the variations in the volumes. Depending on the features of the subcomponents, some categories is not good for shipment, ex. Foam under the "top hats" within the seat is a rather bad shipper with also a low production tooling value, which this naturally makes a business case to have the production tooling for foam localized. So components such as foam was not chosen for analysis in this study because of their obvious production tooling decisions.

The focus of this study will be on the front structure of the seats for the SPA platform, as the component is well able to represent other body components in the seat system which are of high tooling cost. Volume is one of the critical factors that affects the tooling decision because it is a strong input parameter in the TARR analysis where investment alternatives are compared.

With the increase of volumes in China it is interesting to analyse the Chinese volumes. The sourcing scenarios for the SPA front seat structures that will be analysed in this study are:

- Localized production tooling in Europe and ship Chinese volumes to China
- Localize another set of production tooling in China for Chinese volumes

The analysis on production tooling decision in Europe is not necessary, since investments in tooling are already made for the European volumes.

## Commodity 3: Subframes

The subframes for the new CMA platform have been sourced by Volvo Cars sister company China Europe Vehicle Technology (CEVT) and the product buyer has not been involved in that process. The subframes have been sourced by Volvo Cars for the SPA platform where the price of a component is a hundred thousandth of the cost of production tooling. The SPA subframes are segmented into two parts. Firstly the front subframes, which are same for both the 60 and 90 cluster cars and where the front subframes for the 90 cluster is a carry back from the 60 cluster. Secondly we have the rear subframes which consist of several variants as seen in figure 4.7 below. The high variation of rear subframes creates complexity and diminishes postponement possibilities. The high variation also drives logistics cost in form of safety stock. Thanks to its bulkiness the subframes are not grateful to transport long distances or store on shelves. The subframes are also a “slave” to several other powertrain components, which means that if there are changes in other power train components the subframe will also have changes. This in turn requires changes at the supplier’s tooling and production setups. When a change occur Volvo Cars treats it in two ways, either by final consumption, which means that all subframes in the pipeline are consumed before the updated subframe is released. The other scenario is when a subframe is changed and needs a clean cut, this means that all subframes in the pipeline becomes obsolete and needs to be scraped.

Subframes creates a lot of tooling spending that is why it has been positive to ship them to China even though the transport cost is 50 % of the part price. The car project defines a program affordable, which is a budget for tooling and other investments for the project. As long as the buyers are under that value it is approved. If the buyer can come under that value it is a cost saving and the buyers are measured on yearly cost savings. The cost saving KPI is 3.5% yearly.

The focus of this study will be on the SPA front subframe because it is the same for all clusters in the SPA platform.

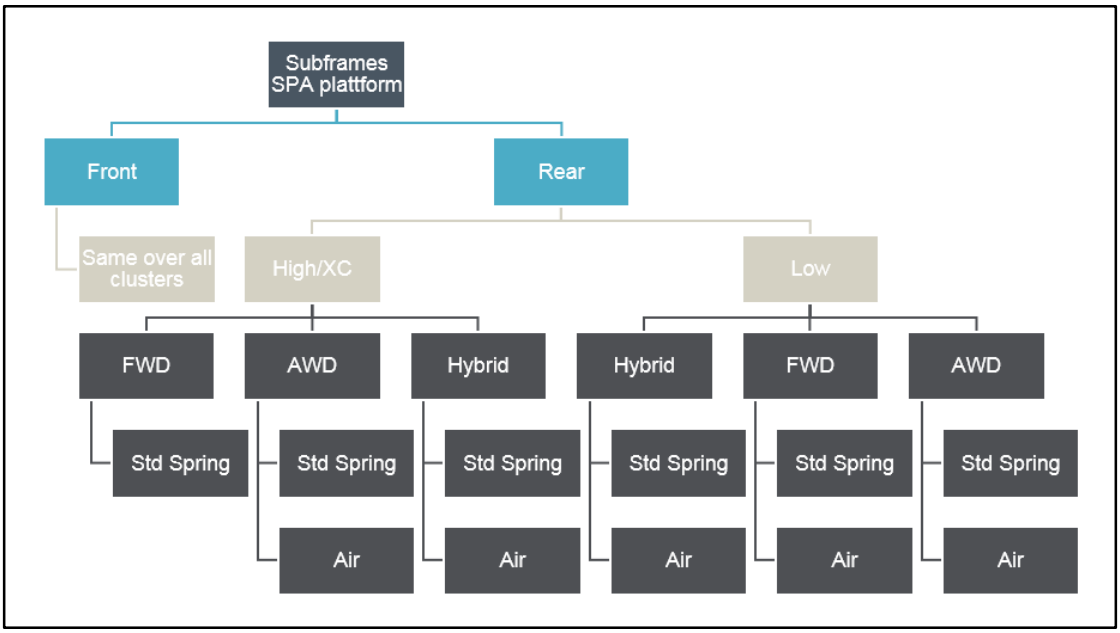


*Figure 4.7. The subframe variation tree.*

Volvo Cars were producing front subframes in a supplier's plant in Europe, which reached its maximum capacity. An investment in doubling the capacity at that supplier were made and a contract was signed. Later a fourth of the needed volume of front subframes were moved to a new Chinese supplier. So the European supplier now had three quarters left and were complaining on the utilization rate of their investment in facility and equipment. There is a plan to make the European supplier work extra shifts to swallow the volumes for the initial US volume needs, which is forecasted to a volume the supplier can handle and when the volumes are known and hopefully increasing for US a new tooling investment decision can be made. The buyers for subframe have tried to find a business case to localize the production tooling in US but the initial forecasted volumes are too low to plead an investment in a new set of tooling. The tooling for a new line in Europe is expensive but to extend an already existing line with additional capacity is often cheaper, around a quarter of the cost. This type of comparison of investments is called Time-adjusted rate of return (TARR) analyses and the buyers send data to the finance department who performs the TARR analysis.

The sourcing for the front subframes were pre sourced by Volvo Cars in 2008 because of the financial crisis Volvo Cars needed to motivate the suppliers to continue producing for them and did this by agreeing on accepting the suppliers to produce for Volvo Cars for a long time i.e. for the whole SPA platform. The sourcing for the volumes in China were exposed for competition. The commodity buyers says that one should avoid to pre source because it often end up in uncompetitive prices on the component this is because the price is only controlled by historical prices and the cost estimators knowledge.

The study need to verify whether it is profitable to have double tooling in US, which lead to the following scenarios to be analysed:

- Localized production tooling in Europe and ship US volumes to US

- Localize another set of production tooling in US for US volumes

The analysis on production tooling decision in Europe is not necessary, since investments in tooling are already made for the European volumes.

## Commodity 4: High voltage batteries

High Voltage refers to batteries equal or above 400 volt. The high voltage batteries comes in a battery pack with 65 cells that is designed by Volvo Cars. The new SPA platform cars comes with a variant a hybrid engine including on pack of high voltage batteries. There goes one battery pack in each hybrid variant SPA car. The supplier is Korean based and the production tooling set is placed there. The battery packs is one of Volvo Cars most expensive component which highly impacts the capital tied-up for the company. The SPA platform cars that uses battery packs are assembled in Sweden and China so the battery packs needs to be shipped from Korea to these locations. The battery is connected with the collision sensor, so when a collision is about to happen, the battery will lock itself, to prevent the danger of burning and explosion. 65% of the battery pack consists of battery cells. The output effect of the battery pack and is limited because of the space in the car. The more space the more cells the more kilowatt hours. The cells are getting cheaper and more efficient as the technology evolves hence are more effect from less cells expected in the future versions of cells.

During the Program Purchasing and planning Volvo Cars scanned and investigate the market and their internal capability to develop batteries. Volvo have small possibility to develop the battery by itself, so they decided to buy the whole battery setup and support the development. During the sourcing approach four to five battery suppliers were identified and some of them were disqualified because of technical issues, cost issues, or contract with competing companies to Volvo Cars. There are some European suppliers but their system does not fit to Volvo Cars battery structure, and they are on the wrong cost level. So one Korean supplier in the end got the business, and the supplier have been growing all since Volvo Cars signed them.

The Volvo Cars unique tooling set for high voltage batteries has a capacity that is forecasted to reach its maximum in 2018 so the buyer have initiated a negotiation about increasing the capacity and hence also tooling to cope up to 300% of the current capacity. Some of the tooling need to be upgraded or some of them need to be doubled.

The battery supplier currently have production in US. If Volvo Cars decides to produce hybrid or electric cars in US it should not be a problem to localize if the volumes are high enough. The supplier also are currently setting up production of batteries in China. There is a possibility to localize the Chinese batteries in China in the future. The supplier is also investigating the possibility to starting up production of battery packs in Europe where they believe they can supply Volvo Cars and other automotive companies. The scenario where the European high voltage batteries need is sourced from a European supplying plant will be used in the analysis of this thesis, even though this is not a real life case for Volvo Cars yet. The authors will do this to evaluate the impact of the additional parameters and since the price of a high voltage battery is very high the hypothesis is that the additional will have a significant impact on the future

production tooling decision. The hypothesis will be tested and the result is presented in the following analysis chapter.

Because the capital tied up from when the high voltage battery is delivered from factory in Korea to assembly plant in Torslanda is so high there is a pilot project currently running within the SCM Finance department of Volvo Cars looking at a possibility to sell the goods to a bank while the components are on a container ship to free up the tied up capital by paying an interest rate to the bank for owning Volvo Cars' asset during it is in transit. The roll out if this project is postponed, because MP&L department wants to further look into the potential effects of such implementation.

High voltage battery is a high cost components, it is actually one of the most expensive component in the hybrid car. The supplier of the high voltage battery have a cell production, and supply based in Korea. At present, the Volvo is shipping batteries packs from Korea to Europe. The study need to verify whether it would profitable to have a European supplier for the battery pack going to the European plants and hence invest in double tooling in Europe, which leads to the following scenarios to be analysed:

- Localized production tooling in Korea and ship European volumes to Europe
- Localize another set of production tooling in Europe for the European volumes

Since there is no current sourcing decision taken on localizing supply in Europe the authors have created a scenario for this by assuming the same cost of piece of component and same production tooling investment as at the existing Korean supplier. The only difference is the landed cost since the battery packs then does not need to be shipped the same distance if supply is localized in Europe.

## Commodity 5: Fuel tanks

The fifth commodity chosen for the study is the Fuel tanks, it is a large component, consumes a lot of space during transportation due to the large amount of air in the tank and is thus considered as an undoubtedly bad shipper for whom localized production tooling is the norm. Volvo Cars currently have localized supply of fuel tanks and hence localized production tooling for the volumes in Europe and China. The fuel tanks consist of as many as sixteen variants divided in four categories after the size of its capacity in volume (litres). And for each category there are variants used for the different markets as can be seen in the figure 4.8 below. The difference in market requirements come from local regulations in choice of material among else.

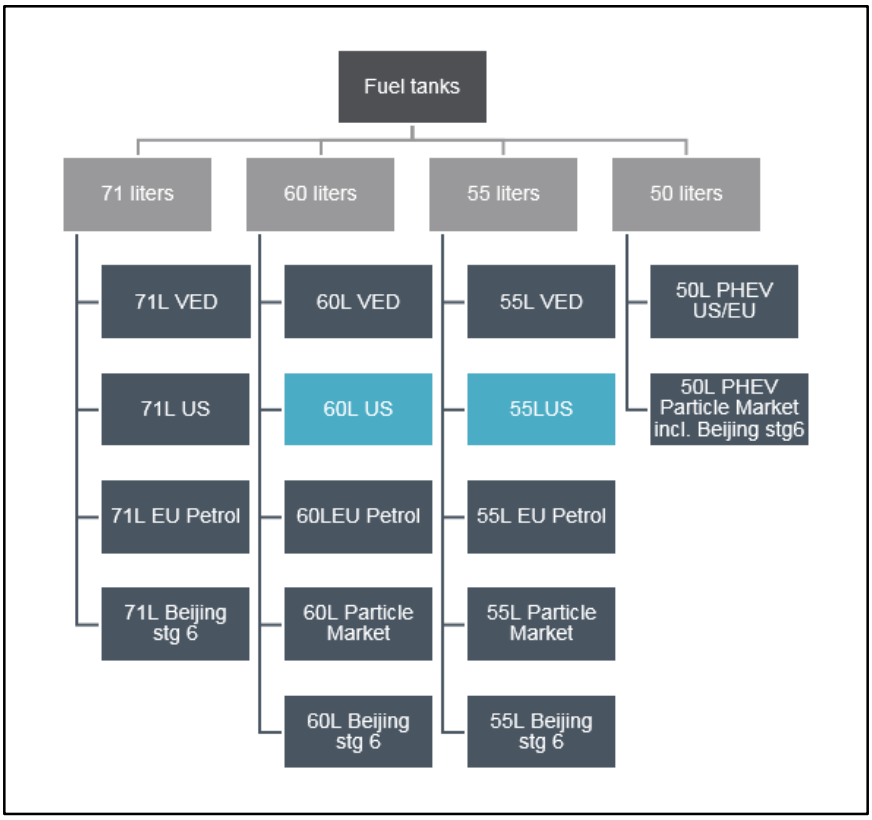


*Figure 4.8. The fuel tank variation tree.*

There is currently an ongoing sourcing for the fuel tanks that will be used in the future plant in South Carolina, US. The ongoing process of fuel tanks are the market test, aiming at market testing the new 55 litres and 60 litres fuel tanks and their volumes for the coming US plant in order to decide the directions for the supply footprint of the these fuel tanks. The representative case used in this study, coloured in blue in the above figure, is set to the US 55 litres and 60 litres tank to evaluate the tooling decisions for those.

A set of production tooling needed to produce a fuel tank consist mainly of the tooling inside an entire blow moulding production line. The purchasers have compared several quotes from the potential suppliers with the existing sourcing model and the TARR analysis supports the investment in a third set of production tooling in US. This study will analyse how much more convincible the TARR analysis gets if using the authors revised sourcing model.

Following scenarios will be analysed for US 55 and 60 litres fuel tanks in this study:

- Localized production tooling in Europe and ship Us volumes to US
- Localize a third set of production tooling in US for the US volumes

The study will not investigate deeper into Europe tooling localization since the US was not in the development plan when the production started, and the tooling need to be created in Europe to start the production. Therefore, the focus on the analysis will be on whether it is still profitable for

Volvo Cars to have localized tooling in US when taking the additional parameters of tied up capital from lead time and flexibility.

## 4.8 Adding parameters to the current sourcing model

The authors of this study will add parameters to the existing sourcing model to create a revised model to reflect the tied-up capital driven by two parameters. Firstly the tied up capital from lead time from order of an item to the receival at Volvo Cars destination of the same item. Secondly the tied up capital from safety stock that is held to enable Volvo Cars to constantly fulfil a certain and fixed service level towards production. If the service level is fulfilled this enables Volvo Cars to be flexible and responsive in terms of disruptions and demand fluctuations.

### 4.8.1 Tied up capital driven by lead time

Business cases helps Volvo Cars to choose the best supplier for each sourcing. Each supplier choice is based on cross functional input and a business case driven by buyer at the purchasing department and lead by the sourcing process gates approved by the purchasing and R&D managers. Purchasing shall always use a landed cost calculation for supplier comparison and choice of supplier. The landed cost at Volvo Cars includes costs such as: Part price per piece, Transportation costs, Packaging costs, Customs costs, Capital Costs and Inventory and handling costs (see figure 4.9 below).

The Landed Cost Specialist is a person responsible for the landed cost calculations at Volvo Cars. The landed cost analysis is done at every sourcing decision for every part flow whether it is for a whole vehicle project or a sourcing for a specific commodity or article. The Landed Cost Specialist gets requests from buyers to calculate the landed cost for a variety of sourcing scenarios in each request. The landed cost of each scenario is used in the sourcing model to compare the scenarios.

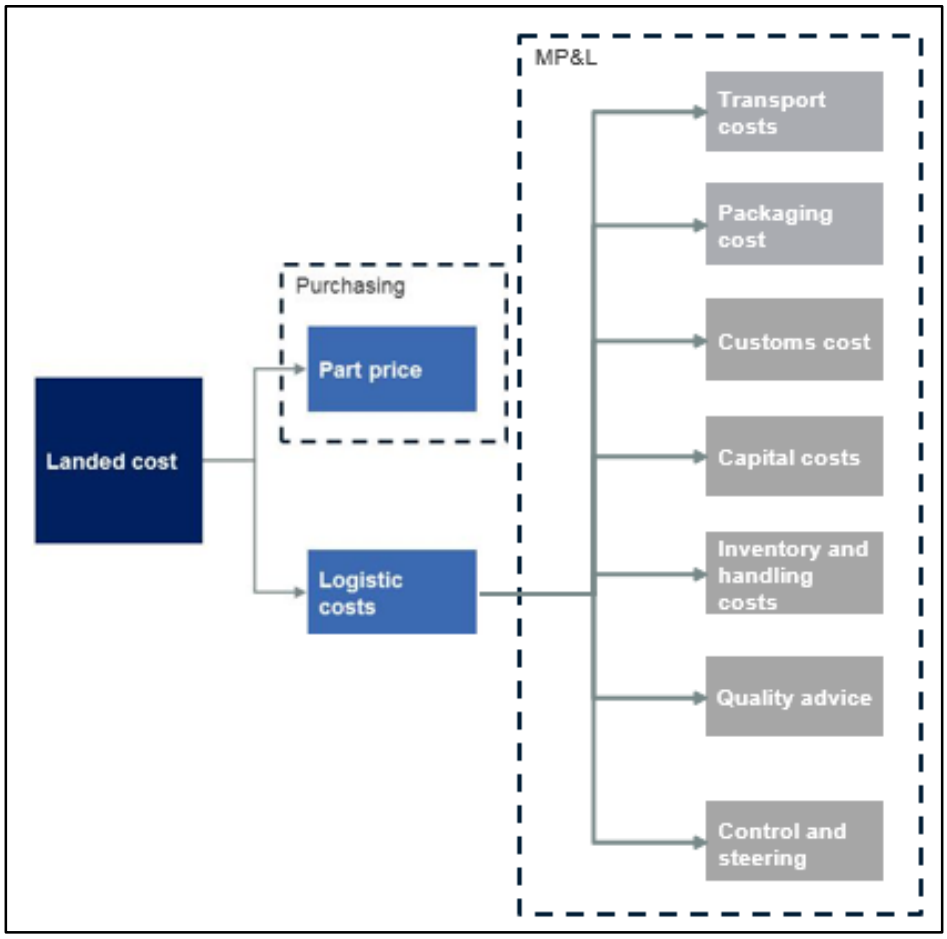


*Figure 4.9. Landed cost at Volvo Cars and its constituent parts (Adopted from interview with landed cost specialist at Volvo Cars)*

The input data needed for the Landed Cost Specialist to perform his landed cost analysis is following:

- Shipping code
- Destination
- Reference part number
- Cost / part including 1-way packaging if applicable
- Currency of part cost
- Commodity and Car Program information
- Weight / part

The landed cost specialist uses a model to analyse the landed cost. Based on the input data above the output is:

- Country from / Country to
- Lead Time
- Localisation recommendation
- Customs cost / part
- Transport cost / piece

- Packaging or repackaging cost / piece
- Total logistical cost / part

The current model does not take eventual volumes already transported for Volvo Cars for other commodities for the route between the shipping address and the destination. It is well known that shipping prices are based on economies of scale driven by volumes on frequently used routes. The current model in not considering transport modes either.

The same component can have different freight costs depending on the yearly volume that Volvo Cars buy, even though it is shipped to and from the same address. The freight cost is not linear, so it is complicated to estimate. 10 000 units / year have a freight cost of 1000 SEK / unit while 200 000 units / year have a freight cost of 300 SEK / units. The same component can also have different freight costs depending on the shipping location. For example inland transportation in China that Volvo Cars currently buy vary between 900 SEK and 25 000 SEK for one trailer, depending on the shipping location and end destination in China.

The landed cost specialist have in a pilot project designed a new tool that is in the test phase soon ready to be deployed as the new landed cost model. It will do better and more precise calculation, which makes the result more reliable.

The new model consider historical volumes meaning eventual volumes already transported for Volvo Cars for other commodities for the route between the shipping address and the destination. It also consider transport modes. The packaging and repackaging cost in the new model is dependent on volume and destination. Tied-up capital is considered based on inbound lead time from when the goods is picked-up and hence owned by Volvo Cars. Capital is tied-up and hence affected by the weighted average cost of capital (WACC) rate of 13%. The new model can also consider potential rack investments driven by lead time and cost/rack needed to transport the goods. The same cost of tied up capital from lead time calculation is used in this study.

Data input in the new tool:

- Data from the supplier info system
- Data from the packaging and part numbers system
- Data consolidator from packaging dimensions system
- Inbound purchasing system for transport costs
- Historical volumes
- Packaging: costs for (re)packing
- Finance: Exchange rates
- Stock matrix: Amount of stock dependent on volumes and lead time
- Localization recommendation from MP&L
- In total over 110.000 lines of (historical) data

The interviewed landed cost specialist said that Volvo Cars categorises its production within following five categories and that all our commodity groups are within the last one:

- Stampings

- Engine
- A-Shop - Body in White
- B-Shop - Painting
- C-Shop - Trim and Final

The landed cost specialist also mentioned that Volvo Cars currently does not split the one way packaging cost and the part price today, which makes it hard to analyse the landed cost for the packaging and emballage. The landed cost does not consider the second tier suppliers.

The landed cost specialist's new landed cost model guided the researchers to understand how to analyse the cost of tied up capital from the inbound lead time and introduced the researchers to one of the Value Chain development Project Manager within the SQL department who worked on a pilot project about the implications from a move from using safety lead time to safety stock in Volvo Cars inventory management system. The Value Chain development Project Manager's safety stock model will be used in this study to quantify the tied up capital from flexibility.

### 4.8.2 Tied up capital driven by flexibility

According to the Project Managers at the Value Chain Development team within the Supplier Quality and Logistics department US more than a dozen *Free Trade Agreements* and some of them requires that part of the manufacturing process is done within their country otherwise it is taxed at high values. China has even more number of trade agreements. The requirements in these trade agreements can be seen as an incitement for Volvo Cars to localise production especially if one consider a high turnover component. The project manager have worked on a way to quantify the cost of enabling a certain production flexibility or responsiveness measured as service level, which in turn requires a certain level of safety stock to enable that service level. The level of safety stock is derived from calculating the forecast accuracy which consist of the forecast bias and the forecast precision (see figure 4.10 below) and lead to something called weighted covariance which in turn lead to the standard deviation in lead time as was mentioned in the theory chapter of this study.

The forecast accuracy is quantified by the weighted covariance for a chosen component. 33% in covariance is seen as one standard deviation which if multiplied with the average consumption gives the standard deviation in demand. With this data at hand one can calculate the needed safety stock if a certain level of service wants to be achieved.

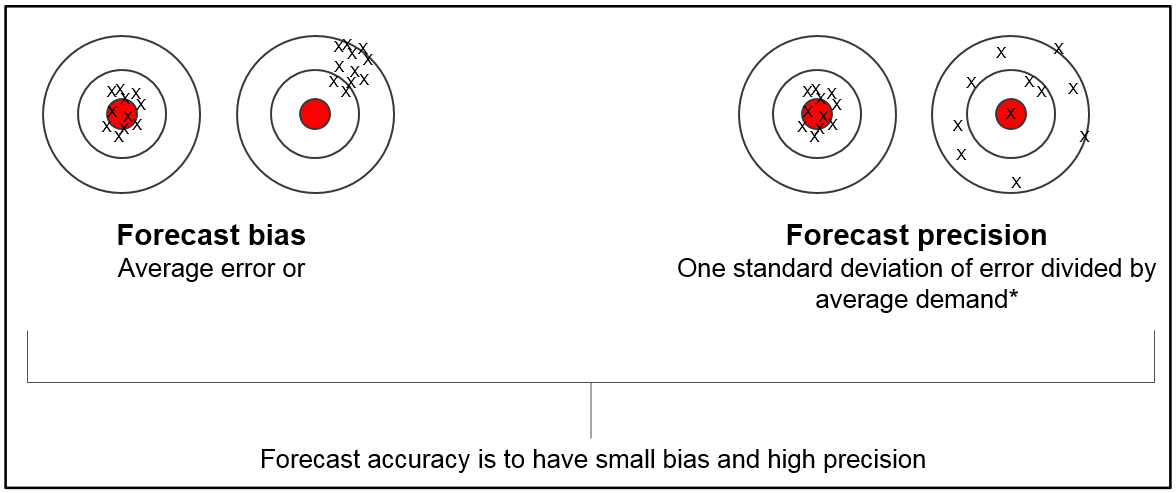


*Figure 4.10. Components of forecast accuracy (Adopted from the interview with the Value Chain Development Project Manager)*

Standard deviation in lead time for one of the Chinese plants will be used as reference for flows going to US. The data for standard deviation in lead time for US is missing since the manufacturing plants is under construction and no historical shipping data for standard deviation exists. What do exist is data over standard deviation in lead time for shipped flows from Europe (and a flow from Japan) that goes via Shanghai where they are loaded on barges. The container finally ends up in the harbour of Luzhou, wherefrom the Chinese plants calls out container loads when needed. In this study's scenarios regarding shipments toward US the average standard deviation in lead time from the Chinese data will be used. The Chinese data set consist of 273 flows from Europe to China and the average of these will be used as reference for the US flows.

Volvo Cars have historically been using safety lead time as the predominant parameter for taking inventory management decisions. While safety lead time is good at handling the uncertainty of deviation in lead time it is bad for handling the uncertainties and deviations in demand. To better handle demand fluctuation for long distance flows the Project Manager at the Value Chain Development department have done a pilot study on how Volvo Cars could go towards the use of safety stock instead of safety lead time. From the statistical safety stock formula a certain service level towards manufacturing can be quantified, and the service level in turn can according to the Project Manager respond to what is referred as the logistic function's level of flexibility also called level of responsiveness in relation to the manufacturing unit.

If Volvo Cars uses the safety stock parameter to represent the service level offered towards manufacturing the tied-up capital of that safety stock can be quantified. Adding the capital cost of a certain service level to the sourcing model can be seen as a way to quantify the flexibility towards manufacturing within Volvo Cars. This study will analyse the cost of capital derived from the stated level of flexibility for the five commodities and add this cost to the business case of the scenarios to understand how much it will impact the production tooling decisions.

The project manager thinks that it could be valuable if the value chain development team would be invited early in the phases of the car platform developments at Volvo Car. This is a cultural change that takes time. To have a production tooling strategy in early phase is a prerequisite for the purchasing to do a good job.

The project manager informed about that Volvo Cars have three types of material flows:

- Raw material
- Batch - used for low variant flows (10-30 variants)
- Sequenced - used for high variant flows (30-100+)
    - Postponement strategy
    - Sequence Supplier: They build near the factory and delivery the parts just several hours before the production demand.

For the batch and sequenced material flows Volvo Cars can apply something called *directed tier 2 suppliers*, which is when Volvo Cars decides which second tier supplier should be chosen for batch and sequence flows. The tier 1 supplier is responsible for the call of commodities and raw material from the tier 2 supplier.

The Project Manager also informed that his colleague is working on a project about Supply Chain Finance, where the project is investigating the possibility to outsource the pipeline to a factoring company at a lower rate than Volvo Cars internal WACC of 13% and then buy it back when it reaches the destination port. This transforms the internal rate to an actual rate. The Project Manager thinks this is problematic since Volvo Cars creates a cost saving because they have set a too high internal WACC of 13%. This gives rise to the question of how to handle the question around the level of working capital.

# 5. ANALYSIS

*The analysis is built with a foundation coming from the theoretical framework and is contextualized with help from the empirical data acquired from the different interviews and data gathered from systems and archives. The focal point of the analysis chapter is to present the results coming out from the analysis of gathered data and is divided in the three following aspects in order to be well prepared for the coming discussion and conclusion part, each of the aspects will be treated in a sub-paragraph.*

The three steps of analysis:

1. Analysis of one historical sourcing case from each of the five commodities and their production tooling decisions with the *current sourcing model* in order to understand the decision on production tooling setup.
2. Analysis of the same historical sourcing case from each of the five commodities with a *revised model* where the additional parameters are included.
3. Meta-analysis of analysis (1) and (2) to indicate the impact of the added parameters and if possible evaluate changes in the decision on production tooling setup

A process map for the analysis step 1 and 2 will be demonstrated and serve as an example in order for the reader to gain the logic and better understand the context of the results. See figure 5.1 below.

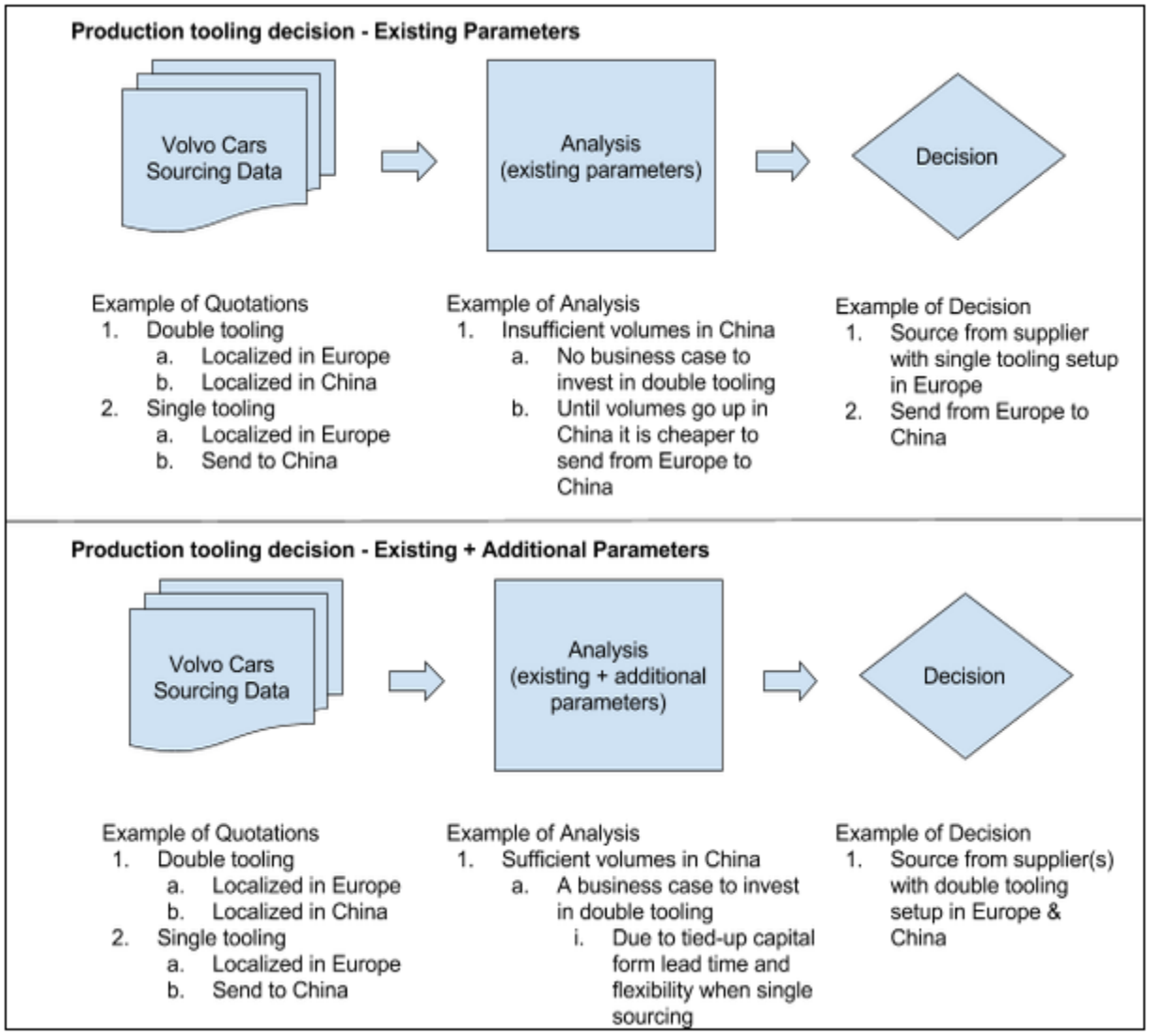


*Figure 5.1. Analysis framework - example of impact from additional parameters*

## 5.1 Production tooling decision analysis

The purpose of this section is to demonstrate the impact of the additional parameters. The analysis and results from both the existing sourcing model as well as the revised sourcing model is presented for each of the five commodities. The analysis on the existing production tooling decisions from the five cases are made based on the existing sourcing model with calculation of the current landed cost and the TARR analysis the authors have gathered from systems and archived data at Volvo Cars, where the TARR analysis compares the saving in landed cost when localizing a second set of production tooling in another region from the size of the investments in production tooling and potential non-capital expenses such as D&D and engineering costs associated with installation of new production tooling. As it was mentioned in the previous chapter, the revised sourcing model contains a revised landed cost calculation taking the additional

parameters of capital tied up from lead time and flexibility into consideration. This revised landed cost is then inserted in the TARR calculation where the impact of the additional parameters can be measured when comparing the TARR analysis results from the existing and revised model by looking at their delta.

One notable point from this study is that Volvo Cars uses a hurdle rate of 75 % in the TARR analysis. Even though the hurdle rate of 75 % in the TARR is standard procedure it was found that not all the production tooling investment decisions are fully aligned to the TARR principle. There are some cases at the purchasing department that production tooling investments are carried out even though the TARR calculation is below the hurdle rate. There are multiple reason for the decision deviation from the TARR, in some cases, the suppliers are refusing to the proposal from Volvo Cars, due to the uncertainties in volumes Volvo Cars can offer; it can also be some commercial negotiations for the leverage of other projects and special deals are made to optimize the overall car project business picture. And similar to what were found in the theoretical framework of TARR, Volvo Cars is as much as possible relying on the TARR analysis, but as was seen during the author's participative observations Volvo Cars takes in supplementary data and use it together with the TARR analysis when taking the production tooling decisions.

## Commodity 1: Steering wheels

As it was mentioned in the Empirical data section, the first scenario for the steering wheels is to send the parts from Europe to China, and the second scenario will be to have localized production tooling in China, both of the cases will be compared by both the existing model, and the revised model to understand the impact of the additional parameters.

The results for steering wheels using the existing model is presented subsequently. With the first scenario of single tooling in Europe the landed cost is 1 872 SEK. The second scenario of double tooling, which has a landed cost of 1 713 SEK and contains a tooling investment, of a second set of tooling in China as well as a D&D cost in total of 6.9 MSEK. The TARR analysis comparing the two scenarios shows a net present value of 111 8 MSEK with a payback period of 2 years and a high value of TARR of 242 %. The hurdle rate for TARR at Volvo is 75%, implying that the decision to go for double tooling in this case is the right way to go.

The next step is to analyse what the value will be when adding the additional parameters of tied up capital driven by lead time and flexibility. The results using the revised model show that the landed cost on the *single tooling scenario* have been raised from 1 872 SEK to 1 932 SEK. The landed cost of the *double tooling scenario* have been raised from 1 713 SEK to 1 717 SEK and the payback period have been lowered from 2 years to 1.7 years.

To conclude, the revised model of the net present value from comparing the scenarios have also been raised from 111.9 MSEK to 155.8 MSEK. With the TARR of 305%, which made it even more convincible to invest in double tooling in China instead of shipping the components from Europe.

## Commodity 2: Seats

Referring to the empirical data in the previous chapter, the increase of volumes in China makes it interesting to analyse the Chinese volumes. The sourcing scenarios for the SPA front seat structures that will be analysed in this study is whether it is a profitable decision for Volvo Cars to use the production tooling in Europe and ship Chinese volumes to China or if Volvo Cars should localize another set of production tooling in China for Chinese volumes. The scenario of sending components from EU to China requiring *single tooling* and the scenario of having another set of localized production tooling in China requiring *double tooling*

The results for the SPA front seat structure using the existing model is presented subsequently. The landed cost of the *single tooling scenario* is 3 679 SEK, while the *double tooling scenario* will lower the landed cost on the component to 2 843 SEK due to the decreased transportation and duty expenses. The investment for the *double tooling scenario* will require capital of 90.8 MSEK for the set of production tooling, however, the payback period for the investment is only 1.6 years, and will generate a landed cost saving of 635.5 MSEK, which, lead to a net present value of 179.1 MSEK, the TARR calculation supports the additional tooling investment since the TARR of the project is at 165%, significantly higher than the Volvo Cars hurdle rate of 75%.

The additional parameters of capital tied up driven by the lead time and flexibility will make the investment even more convincible. The results using the revised model show that the landed cost on the *single tooling scenario* have been raised from 3 679 SEK to 3 776 SEK. The landed cost of the *double tooling scenario* have been raised from 2843 SEK to 2 849 SEK, meaning more saving from the landed cost per part, driven the total landed cost saving from 635.5 MSEK to 705.3 MSEK. Besides, the added parameters have also increased the net present value from 179.1 MSEK to 204.2 MSEK, which, result in an increase of TARR from 165% to 199%.

To conclude, the *new solution* of having another set of production tooling in China is profitable for Volvo Cars. Adding the parameters of tied up capital for lead time and flexibility will make the decision even more convincible.

## Commodity 3: Subframes

Referring to the empirical data in the previous chapter, the subframes are divided into front subframes and the rear subframes, after a discussion with the responsible commodity buyer, the study will be focus on the front subframes and take rear subframe out of the analyse scope. This is not only due the fact of high variations on the rear subframe but also due to the subframe is a typical case to present the whole subframe group. The production tooling case for front-subframe is whether it is a profitable decision for Volvo Cars to invest in another set of localized production tooling in US, or to ship the components from Europe to US. The scenario of sending components from EU to US will be named the *single tooling scenario* and the scenario of having another set of localized production tooling in US will be named the *single tooling scenario.*

The results for the SPA front subframe using the existing model is presented subsequently. The landed cost of the *single sourcing scenario* is 3 906 SEK, while the *double tooling scenario* will

lower the landed cost on the component to 3 177 SEK due to the decreased transportation and duty expenses. The investment for the *double tooling scenario* will require capital of 35.6 MSEK on the facilities and tooling, however, the payback period for the investment is only 2 years, and will generate a landed cost saving of 277.4 MSEK, which, lead to a net present value of 78.2 MSEK, the TARR calculation supports the extra tooling investment since the TARR of the project is at 98%, significantly higher than the Volvo Cars hurdle rate of 75%.

The additional parameters of capital tied up driven by the lead time and flexibility will make the investment even more convincible. The results using the revised model show that the landed cost on the *single tooling scenario* have been raised from SEK 2 906 to 3 943 SEK. The landed cost of the *double tooling scenario* have been raised from 3 177 SEK to 3 180 SEK meaning more saving from the landed cost per part, driven the saving from landed cost from 277.4 MSEK to 290,6 MSEK. Besides, the added parameters have also increased the net present value from 78.2 MSEK to 82.9 MSEK, which result in an increase of TARR from 98% to 103%.

To conclude, the *double tooling scenario* of having another set of production tooling in US is profitable for Volvo Cars. Adding the parameters of tied up capital for lead time and flexibility will make the decision even more convincible.

## Commodity 4: High Voltage Batteries

The high voltage batteries is as mentioned in the empirical data chapter one of the most expensive components in a hybrid car and because of the high value the cost of tied up capital from lead time and flexibility is relatively high. The production tooling case for the SPA high voltage batteries is whether it is a profitable decision for Volvo Cars to invest in another set of localized production tooling in Europe, or to ship the components from Korea to Europe. The scenario of sending components from Korea to Europe will be named the *single tooling scenario* and the scenario of having another set of localized production tooling in Europe will be named the *double tooling scenario.*

The results for the SPA high voltage battery using the existing model is presented subsequently. The landed cost of the *single tooling scenario* is 140 048 SEK, while the *double tooling scenario* will lower the landed cost on the part to 138 158 SEK due the decreased transportation and duty expenses. The investment in production tooling and D&D for the *double tooling scenario* will require capital of 201,1 MSEK, and the payback period for the investment is 4,1 years The *double tooling scenario* and will generate a landed cost saving of 453,3 MSEK, which lead to a net present value of 47,4 MSEK, the TARR calculation does not support the investment in an additional set of localized production tooling in Europe since the TARR of the project is at 24%, significantly lower than the Volvo Cars hurdle rate of 75%.

The additional parameters of capital tied up driven by the lead time and flexibility will make the investment profitable and thus fulfilling the authors' hypothesis of high impact from the additional parameters for the relatively expensive high voltage batteries. The results using the revised model show that the landed cost on the *single tooling scenario* have been raised from 140 048 SEK to

143 750 SEK. The landed cost of the *double tooling scenario* have been raised from 138 158 SEK to 138 509 SEK and the payback period have been lowered from 4.1 years to 2.5 years

To conclude, the net present value of the new solution have also been raised from 47.4 MSEK to 343.8 MSEK. With the TARR of 78 %, which is slightly above the hurdle rate for TARR at Volvo of 75%. This implies that the tooling decision is changed if the author's parameters reflecting tied up capital from lead time and flexibility is added to the sourcing model make the investment in an another set of production tooling a profitable business case.

## Commodity 5: Fuel tanks

As it has been mentioned in the empirical data the new factory being built in South Carolina, US initiates a sourcing process for the decision whether to localize the production tooling in US, or still keeping one set of tooling in Europe and send the components from Europe to the US. The latest decision made from the existing sourcing model was to localize the production tooling, meaning that Volvo need to invest in another set of production tooling in US for the fuel tanks commodity.

The scenario of sending components from Europe to US will be named the *single tooling scenario* and the scenario of having another set of localized production tooling in US will be named the *double tooling scenario*. The results for the 55 and 60 litres fuel tanks using the existing model is presented subsequently. The landed cost of the *single tooling scenario* is 6 748 SEK, while the *double tooling scenario* will lower the landed cost on the part to 3 569 SEK due the decreased transportation and duty expenses. The existing model have shown that having extra tooling in the US is profitable, since the TARR adds up to 158% significantly above the hurdle rate of 75%. Which represents a net present value of 399.9 MSEK and a saving on the landed cost of 1449.8 MSEK. The investment for the tooling is 150.8 MSEK, with a payback period of 3.6 years.

Taken the additional parameters into consideration. The results using the revised model show that the landed cost on the *single tooling scenario* have been raised from 6 748 SEK to 6 795 SEK. The landed cost of the *double tooling scenario* have been raised from 3 569 SEK to 3 572 SEK. The TARR have been increased from 158% to 165%, which still make it a profitable case for the company, followed by an increase on the net present value from 399,9 MSEK to 415,3 MSEK, the saving in the landed cost have also be increased from 1449,8 MSEK to 1496 MSEK. The payback period for both cases is at 3.6 years, even though the additional parameters have been added to the analysis.

To sum up, due to the high transportation and duty cost from Europe to US, localize the production tooling is a profitable decision for Volvo Cars and the impact from additional parameters only makes the business case even more profitable.

## 5.2 Tooling decision summary

A summary of the analysed historical sourcing cases is presented in the table 5 below. The table outlines the impact of the additional parameters for each of the five commodities where the displayed values are in MSEK, expect from the TARR and Cash flow break-even which is in percentage and years. The result from the *existing model* is shown in the upper table section. The additional parameters are impacting the scenarios in the *revised model*, which is seen in the middle table section, thus increasing the savings in landed cost and hence the net saving before tax that in turn improves the net present value of each of the five historical sourcing cases in the *revised model*. The impact of the additional parameter is presented in the lower table section displaying the *Delta*. The *Delta* is referred to the numbers in the revised model minus the numbers in existing model.

Table 5. Summary of business cases and impact analysis of additional parameters

| | Impact analysis of additional parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| Existing model | Commodity | Investment | Savings in Landed Cost | Net Saving Before Tax | Net Present Value | TARR (IRR) | Cash flow break even (years) |
| | Steering Wheel | 6,9 | 351,5 | 344,6 | 111,8 | 242% | 2,0 |
| | Front Seat Structure | 90,8 | 635,5 | 544,8 | 179,1 | 165% | 1,6 |
| | Front Subframe | 35,6 | 277,4 | 241,8 | 78,2 | 98% | 2,0 |
| | High Voltage Batteries | 201,1 | 453,3 | 252,3 | 47,4 | 24% | 4,1 |
| | Fueltanks | 150,8 | 1449,8 | 1299,0 | 399,9 | 158% | 3,6 |

| Revised model | Commodity | Investment | Savings in Landed Cost | Net Saving Before Tax | Net Present Value | TARR (IRR) | Cash flow break even (years) |
|---|---|---|---|---|---|---|---|
| | Steering Wheel | 6,9 | 484,7 | 477,8 | 155,8 | 305% | 1,7 |
| | Front Seat Structure | 90,8 | 705,3 | 614,5 | 204,2 | 199% | 1,5 |
| | Front Subframe | 35,6 | 290,6 | 255,0 | 82,9 | 103% | 2 |
| | High Voltage Batteries | 201,1 | 1257,3 | 1056,2 | 343,8 | 78% | 2,5 |
| | Fueltanks | 150,8 | 1496,0 | 1345,2 | 415,3 | 165% | 3,6 |

| Delta | Commodity | Investment | Savings in Landed Cost | Net Saving Before Tax | Net Present Value | TARR (IRR) | Cash flow break even (years) |
|---|---|---|---|---|---|---|---|
| | Steering Wheel | 0,0 | 133,2 | 133,2 | 44,0 | 63% | -0,3 |
| | Front Seat Structure | 0,0 | 69,7 | 69,7 | 25,1 | 34% | -0,1 |
| | Front Subframe | 0,0 | 13,2 | 13,2 | 4,7 | 5% | 0,0 |
| | High Voltage Batteries | 0,0 | 803,9 | 803,9 | 296,4 | 53% | -1,6 |
| | Fueltanks | 0,0 | 46,2 | 46,2 | 15,4 | 7% | 0,0 |

(Numbers in MSEK) Changed production tooling decision

The delta in *Savings in Landed cost* and *Net Saving before Tax* represents the impact of taking the two parameters of tied up capital from lead time and flexibility into consideration in the authors

revised landed cost calculation. The delta in *Net Present Value* is lower than the *Savings in Landed cost* and *Net Saving Before Tax* since the net present value considers the tax, weighted average cost of capital and the depreciation of capital expenses such as production tooling. But the delta in *Net Present Value* in the multi MSEK category.

The rows for the high voltage batteries component is marked with orange to indicate the recommended change in production tooling decision since the additional parameters for this commodity impact the business case so dramatically that it goes from a low TARR of 24% using the existing model up to a TARR of 78% using the revised model. And 78% is above the hurdle rate within the company, thus approving an investment in an additional set of localised production tooling in Europe. As mentioned in the empirical data of the high voltage battery there was no historical data of a supplier in Europe, but since the buyer of high voltage batteries were investigating the possibility to find a business case for having a supplier in and hence a production tooling set localisation in Europe the authors decided to create a scenario for this. The theoretical scenario was created by using the same tooling investment value as were quoted for the tooling set in Korea and the same piece price were assumed as the ones coming from Korea to. Why the high voltage battery is dramatically affected by the parameters of tied up capital from lead time and flexibility is because it's relatively remarkable piece price. The high price and long lead time from Korea together creates a high cost of tied up capital and the long lead time and the components high covariance drives a relatively high safety stock to enable fulfilment of the stated service level of 98,8% set for the flexibility parameter.

# 6. DISCUSSION

*The results from the analysis section will be mainly discussed in this chapter, the researchers will in this chapter, take an insight on the additional parameters that have been added to the existing decision making model for the production tooling, in order to understand and be critical to the impact of the additional parameters on the final tooling decision. Apart from that, some other factors which are tightly connected and related to the study will also be discussed, such as the WACC value, which was cited from Volvo cars and have been used in all the calculations; Some comments and notables for the TARR value, which was the main decisive factor for the production tool decision; Additionally, one of the strategies for production tooling will also be discussed in this section, since the coming strategy change of production tooling will have a significant impact to the way of working at Purchasing.*

## 6.1 The impact of the additional parameters

Based on the analysis and the analysis summary above, it is obvious that the added parameters of tied up capital of lead time and flexibility can make a difference on the TARR value, which accounted for the main factor of the decision making on production tooling. The carried out study is crucial for Volvo Cars to be considered, as capital tied up is significant especially for Volvo Cars who invest heavily in the transformation of the company and, who aims at developing and launching several different car models at the same time. Developing various car projects simultaneously need the company to improve their management of tied up capital in order to better utilize its financial resources which are far away from infinite. This study have shed light on the tied up capital from the two factors lead time and flexibility based safety stock and quantified these into parameters to be used in an automotive company's sourcing model. Theses parameters have been assessed by adding each of them into an existing sourcing model. The authors then identified one historical but relatively recent sourcing for five different components and compared the output from the automotive company's existing model with the revised model including the two parameters. The comparison derived in the impact of the parameters on the landed cost of the components. As can be seen in the figure 6.1 below the two additional parameters as percentage of the landed cost per piece of component is relatively low compared to the piece price and logistics and duty cost. Something interesting and can be seen in the figure 6.1 below is that the cost of tied up capital from lead time is actually larger than the whole logistics and duty cost of the high voltage battery and this along with the long distance thus long lead time can explain why the authors additional parameters can so dramatically improve the TARR and hence the business case for the double tooling scenario of the high voltage battery.

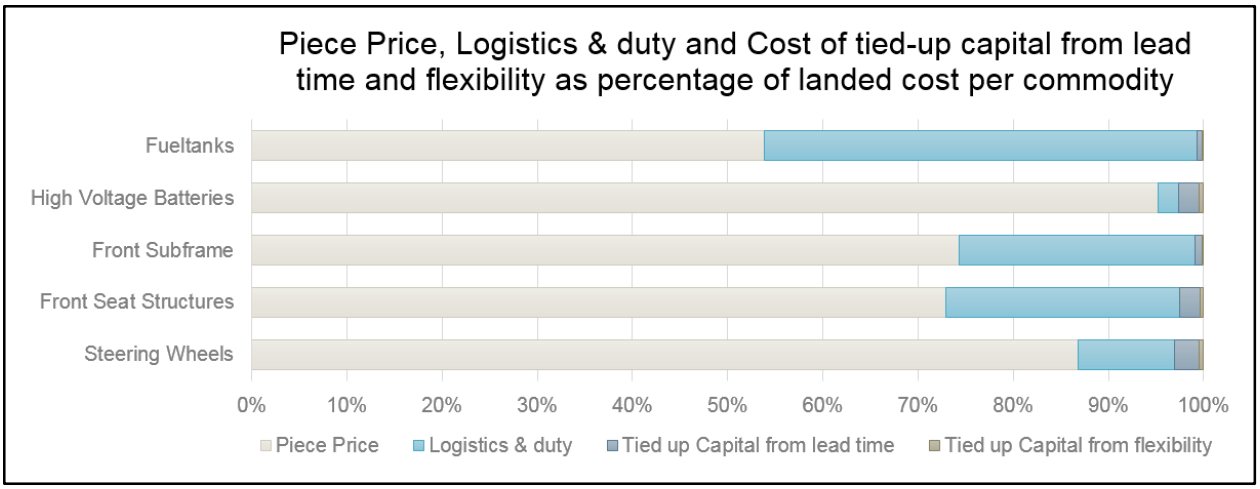


*Figure 6.1. Impact of tied up capital from lead time and flexibility on the landed cost*

Figure 6.1 above exhibits the impact of the impact of tied up capital from lead time and flexibility on the landed cost per piece and the impact per piece seems relatively low if compared with the piece price and logistics and duty cost. But as was revealed in the table 5 in the analysis summary the impact of the two parameters when multiplied with the whole life cycle volume add up to substantial amounts of money. This substantial additional amount of capital tied up from lead time and flexibility when a company decides to ship components long distances instead of having localized supply or production is presented and shed to light in this study. Then if companies find the levels of impact from the author's parameter to be significant enough to act upon is up to the company to decide.

As it was mentioned in the analysis chapter, all the projects that are above the TARR threshold value of 75% is considered to be valid business cases, while a TARR below that value will be rejected. If a TARR is very close to the hurdle rate the business case can be deeper analysed, with for example a sensitivity analysis where the input value in the TARR can be slightly increased or decreased to test how changes in criteria and assumptions in the business case affects the profitability of the case. This can be done to broaden the understanding of the relationships between input and output variables in the model. An example of a deep dive in the TARR analysis is when the scenarios from a sourcing for a component used in a coming car project is set side by side and scrutinized in detail. When one of the scenarios for example a double tooling scenario is close to the hurdle rate of the TARR, slightly under 75% in Volvo Cars case, but showing a relatively short payback time and have the potential to solving a capacity issue of a bottleneck operation the finance controller can do a sensitivity analysis to see how much impact a lowered currently or raw material price can have on the output of the TARR and for example how much a slight increase in volumes can impact the case. A sourcing case can be approved even if it is under the hurdle rate but very close and if the investment in the case is within the budget of the car project. And this example shows the real value and power of the TARR analysis. What the authors have come to understand while finishing this study is that the TARR analysis should be seen as guidance when making investment decisions rather than a decision tool in itself.

For the four commodities fuel tank, front subframe, steering wheel, and front seat structure, the TARR have been increased from the old value of 158%, 98%, 242% and 165% to the new values of 165%, 103%, 305%, and 199% respectively. The increase on the TARR value showcases that the added parameters have made the investments even more convincible for the company to carry out. Apart from that, it can also be revealed that the increase was different on the TARR among the four mentioned commodities, this is due to the fact of that there is a difference in part volume, lead time, standard deviation in demand, as well as the difference in part price, some of the commodities have much higher price, and by logic, when adding the parameters to the landed cost it will eventually increase the TARR value, that indicates it is more necessary to localize the tooling.

The only exception can be found in the commodity of high voltage batteries, although the European supplier was a fictive one. The TARR calculation from the existing decision model showed that having extra tooling in EU is not a wise decision for Volvo Cars to take as the TARR rate was at 24%, far lower than the hurdle rate. Including the additional parameters in the revised model have increased the TARR from 24% to 78%, which totally have turned the case upside-down, meaning that it is profitable for Volvo Cars to invest in a second set of production tooling at an European suppliers to serve the local market instead of shipping the parts from Korea to EU. The dramatic change on the TARR value was mainly rooted from the change of landed cost saving that have been increased from 460 MSEK to 1300 MSEK. The change of landed cost saving in turn have made an impact on the net saving before taxes and the net present value, both value have been turn to a positive direction when adding the additional parameters and comparing with the assumption of having a fictive supplier in Europe. To utilize the result, it would be wise for Volvo Cars to investigate the possibility of having a European supplier for high voltage battery, or to have discussion with the existing supplier on the future possibility of establishing a factory in Europe. The advantage of having global footprint discussions with existing supplier lies in the fact that, it will be easier for Volvo Cars to get more long term leverage from the existing supplier as well as lower the part price by having the strategic economies of scale.

## 6.2 The trustworthiness of WACC

Volvo Cars have employed a WACC rate of 13% when evaluating the investment projects, the authors of this study have been critical to the rate and have been in contact with the finance department at the company to understand the context of selecting 13% as the rate for weighted average cost of capital. The authors were questioning the high level of WACC used when calculating business cases within the company in relations to the current cost of capital in the market, which at current is way below 13 %. It was found out that the 13% rate for WACC is not a unique value for Volvo Cars, but it is an industry wide standard value that is applied among other car manufacturers as well. According to the explanations from the finance department, the capital of the company come from mainly two sources, debt and equity. In the daily operations, after the company have paid out the debts, which are necessary for running the projects and production operations, the capital left overs (cash) which are not paid out to the shareholders in the form of dividends will be kept on the account on behalf of shareholders. The detailed

information which in the case of Volvo Cars´ 13% is by commercial reason not able to be revealed to the researchers, although it is generally a similar number within the industry. However, the financial department did raised an example which can be applied to understand the origin of the WACC value. For instance, if the debt holder requires a return rate of 10%, while the shareholders would require a return of 20%, then the company usually will calculate the average value to balance these two parties and the average balance value will be applied as a standard for evaluating the investment projects, so the company will be able to satisfy debt and equity holders. In this case, the WACC is 15%.

## 6.3 Supplier owned production tooling

During the time of this study, there have been discussions around the Purchasing department that the tooling ownership policy may be changed in the near future. The change of tooling ownership program refers to the change of Volvo Cars owned production tooling to Volvo Cars only own the production tooling where it is critical for the company to keep, apart from that, all the rest of the production tooling will be seen as “non-critical” and therefore the ownership of the tooling will be transferred from Volvo to the suppliers.

The new tooling ownership programs aims at free up more working capital and to be able to invest in more costly programs, which, may yield higher turn over to the firm. The critical tooling ownership list is updated and maintained by the business analyst.

The new tooling ownership decision may decrease the pressure for Volvo Cars to make tooling analysis in the future, but Volvo will still benefit from this study since the rest of tooling which are on the critical ownership list is around 200st, understanding the capital tied up and the connection to lead time and flexibility will provide future guidance on the critical tooling decision. There will be on-going questions internally regarding the new introduced policy, and the Purchasing organization is also expecting questions or even complaints from different functional groups and suppliers. The concerns which were previously been discussed by either internal or external parties, were, for example, what happens if Volvo change the part or even delete the part from the production while the suppliers are being told that the life time span of a tooling is 7 years. How will Volvo pay up the compensation to the suppliers? The new introduced policy will make an effect on how the purchasers negotiate with the suppliers, as the suppliers will include the tooling cost into the part price, which may change the way all the purchasers have used to work.

## 6.4 Flexibility as end customer service level

The notion of flexibility is wide as an ocean, which implied a need for the authors to delimit the study to a specific part of flexibility. This study analyses flexibility from a material planning & logistics perspective looking at how a supply chain setup measured by a fixed service level, aimed at consistently being fulfilled, could enable the adequate flexibility towards the production flow in terms of relatively low probability of production flow inventory stock out. What could be interesting to further analyse is how to create the capable and sufficient flexibility throughout the end to end supply chain looking at not only the inbound flow going into the production operations but also the

outbound flow towards the end customer. A study looking not only at the internal customer, in this case the production but also the at how to analyse the flexibility towards the end customer would be valuable since the level of complexity increases with the globalization of an organization's footprint since lead time increase within the often increased supplier network. Taking Volvo Cars as an example managing the high amount of variants of cars but also car models and the world wide spread customers possibilities to customize the equipment, materials and colours of the car models creates enormous complexity and requires advanced supply chain setups. Setups such as long distance just in sequence flows and component postponement strategies to be able to offer the level of flexibility demanded by the customers who seldom want to wait several week for the delivery of a purchased car. This is why an analysis on how to quantify the end customer flexibility or end customer service level would be interesting to perform and if possible incorporate in the company’s sourcing model. Especially interesting in the context of automotive industry.

# 7. CONCLUSION

*This study has analysed five historical sourcing cases across five commodities within trim & final at Volvo Cars Corporation. The two main areas that have been analysed to reach the aim of improving the production tooling decisions making process at Volvo Cars are: (1) how an automotive manufacturer take production tooling decisions when cars are produced in more than one region and (2) how much influence the additional parameters of capital tied up from lead time and flexibility can have on existing production tooling decisions for an automotive manufacturer.*

The production tooling decision process at Volvo Cars are a part of the sourcing process. The authors have analysing the sourcing process found data to answer on the analysis area (1). The purchaser will go through the purchasing meetings to firstly get the suppliers approved, as it have been mentioned in the previous chapters, from Sourcing approach meeting, through sourcing quotation, and sourcing consensus to sign the agreement. During the above-mentioned Purchasing process, the total landed cost suggest which land is the most profitable for Volvo to produce, all the suppliers will be evaluated based on the calculation. At the same time, the purchasing department will order a TARR calculation from the finance department which take the landed cost as well as net present value into consideration from the finance department. The TARR value will suggest if the tooling investment is a positive decision to make. However, the prerequisite for having the TARR analysis is that there is a budget for extra tooling, otherwise, it is only to decide the production site, even though it is very profitable to have extra tooling.

The idea of comparing Volvo Cars existing sourcing model with a revised one has enable the authors to answer on the analysis area (2), the impact of the additional parameters. The parameters of tied up capital from lead time and flexibility has been quantified by the creation of formulas which have then been used in each of the five historical business cases. The cost of the tied up capital from lead time and flexibility have then been added to the landed cost, which when inputted in the TARR constitutes the revised model. The impact of the parameter has shown to be financially substantial for each of the five historical cases where the total increase in savings from landed cost caused by the additional parameters for all five cases sums up to roughly a billion SEK over the lifetime of the car project the components are incorporated into. This study has shed light on the amount of influence the additional parameters are creating. The authors look forward to present the findings from this study to Volvo Cars. It is then up to the DM&PP's management within Volvo Cars to decide if the influence of the additional is significant enough to act upon. If it gets decided that the parameters are significant and should be added to the existing sourcing model this study will come good at hand explaining how to do it.

# 8. FURTHER RESEARCH

*Apart from what have been summarized and concluded in the previous chapter, there are still some aspects of the study that are suggested by the researcher to be further investigated. The investigation can either be initiated from the academic point of view, or, it is also beneficial for the company to document the following aspects which can be utilized for further improvement projects.*

## 8.1 Supplier owned tooling for core commodities

The first area that is suggested to be further investigated is the newly introduced tooling ownership policy that Volvo Cars will only own the tooling which belongs to the core commodity and the tooling ownership of all the new sourcing projects which are not within the core commodity area will be directed to the suppliers. As it was noted in the previously section, this is a new policy initiated from the management team, the thesis project have already been started by the time of the new policy. So the newly introduced strategy have not been fully taken into the scope of the research, as a large number of the research prerequisite and strategy need to be changed accordingly. Besides, the core 200 commodities still need the improvement to existing production tooling decision making model, therefore, the research scope have not been changed. It is strongly suggested that the further research could be to investigate the optimal process for defining the core commodity; the researchers can focus on the different theories for defining the core commodity, and the project leaders at company can work on with cross functional cooperation to define decisive parameters and process that are helpful for defining the core commodities from the practical point of view. The researchers and the relative project leaders can then carry out different workshops and discuss sessions to improve the existing parameters and process for deciding the core commodities. Besides, it is also recommended that the company investigate an optimal way and guidance for purchasers to carry out commercial negotiations based on the new policy, and make study on the supplier claims on the new policy in order to make sure that the supplier relationship is not weakened by the new strategy, and suppliers are getting more motivated for future cooperation with Volvo Cars.

## 8.2 Further investigation on WACC

The second suggested research area have been discovered from the commercial perspective. At present, Volvo Cars is applying the WACC of 13% for evaluating the investment projects, according to the origin of the WACC that have been introduced in the previous chapter, the WACC is a balanced value between the equity holder and the debt holder. Since the WACC plays an important role in defining the decision of a business project, it is important to understand the impact of WACC value on the final investment projects, one of the possible ways could be to carry out sensitivity analysis on the value to see how the final results are being affected. The researchers are also encouraged to investigate whether there is a difference for WACC for within different areas at Volvo Cars, since it is certain that WACC of 13% is applied at Direct Purchasing, it is worth to investigate whether it is also the case for Indirect Purchasing, which function is to purchase products that are not directly used on the products. The area of Indirect Purchasing can

vary from Production lines, machinery, to infrastructure, fixed assets, etc. The investigation can relating to what WACC value have been applied when making investment at Indirect Purchasing; does the WACC value differs from area to area; What are the reasons if the same WACC value have been applied, what are the reasons if not. So the researchers can get an overall understanding of the WACC value by carrying out the above mentioned studies. From the company perspective, the company can build broader knowledge on WACC on different areas, and this may arouse new thoughts on the WACC value, which may lead to further improvement projects.

## 8.3 Flexibility in terms of end customer service level

The third and last area that is suggested to be further investigated is the flexibility from an end customer service level instead of production flow service level as this study have been delimited to. As mentioned in the chapter 6.4 this study insinuates a need for further research within the notion of end customer flexibility and how to quantify and incorporate such a parameter within the sourcing model of an automotive company.

# 9. FINAL CONTEMPLATION

Performing this study at Volvo Cars has contributed to several lessons, on various levels: from personal to both professional and academic. Spending almost six months at the automotive manufacturer's headquarters in Gothenburg have given tons of knowledge and insight about the automotive industry in general and purchasing of car components in particular. Having the opportunity to sit in the same room as the purchasers and carry out participant observations in parallel with the research structuring and data gathering have without a doubt deepen the understanding of the context and the individual purchaser's day to day tasks and duties.

The fact the authors have the two different academic specialisations of supply chain management as well as quality and operations management and managed to find a research topic in the intersection of both academic disciplines applicable within the company has been particularly exhortative. This uniting research topic has given birth to many interesting discussion and learning experiences for the two authors were both theory and empirical observation has been deeply analysed until late evenings at the, by them almost deserted, Volvo Cars premises.

After have studied the sourcing process and especially the decision process for production tooling in real time the authors have realized how complex and intertwined many of the purchasing decisions are. The current role of a purchaser is far from transactional and long gone are the operational purchase orders performed by the command from the engineering department.

By working on this thesis the authors have got insight in how today's purchasers handles sourcing for global manufacturing footprints with complex supply chain setups in diverge supplier networks. And how a purchaser in order to present a promising business case needs to understand, everything from corporate finance, statistical analysis, logistics, operations and quality management to corporate governance, supplier relationship management and negotiation techniques. Many of the purchasers met during this study held master degrees in either engineering or economics and some of them have previously been working within the R&D and design departments before jumping to purchasing.

Finally, it must be pointed out that it has been a true privilege to perform this study at the increasingly global and highly progressive automotive manufacturer. By working on and finalizing this study the authors have gained nothing else but great inspiration to themselves pursue a career within purchasing. The results and learning experiences from this study could not have been accomplished without the help and support by all the wonderful people involved at Volvo Cars.

# REFERENCES

## BOOKS, REPORTS AND DATABASES


Blome, C. (2009). Single versus multiple sourcing: A supply risk management perspective. (pp. 125-135). Boston, MA: Springer US.

Bolotova, L., & Zander, H. (2009). A comparison and evaluation of incoterms and their effect on the landed cost and logistic performance Chalmers University of Technology, Göteborg.

Bryman, A. Bell, E. (2011), *Business Research Methods*, Oxford University Press.

Cai, S., Yang, Z., & Hu, Z. (2010). The effects of volume consolidation on buyer–supplier relationships: A study of chinese firms. Journal of Purchasing and Supply Management, 16(3), 152-162.

Chen, I. J., & Paulraj, A. (2004). Towards a theory of supply chain management: The constructs and measurements. Journal of Operations Management, 22(2), 119-150.

Chopra, S., & Sodhi, M. S. (2014). Reducing the risk of supply chain disruptions. MIT Sloan Management Review, 55(3), 73.

Cohen, L., & Young, A. (2006). Multisourcing: Moving beyond outsourcing to achieve growth and agility. Boston, Mass: Harvard Business School Press.

Costantino, N., & Pellegrino, R. (2010). Choosing between single and multiple sourcing based on supplier default risk: A real options approach. Journal of Purchasing and Supply Management, 16(1), 27-40.

Davidson, B. and Patel, R. (2011) Forskningsmetodikens grunder. Edition 4:1. Lund: Studentlitteratur AB.

Dubois, A., Fredriksson, P. (2008). Cooperating and competing in supply networks: Making sense of a triadic sourcing strategy. Journal of Purchasing and Supply Management, 14(3), 170-179.

Emmanuel P. Papadakis, CraigH. Stephan (1998). Engineering Costs and Production Economics, 13 (1.988) 111-124 Elsevier Science Publishers B.V., Amsterdam, INSPECTION DECISION THEORY: DEMING INSPECTION CRITERION AND TIME-ADJUSTED R

Ethics in social and behavioural research, E DIENER; R CRANDALL, (1978)

Fang, J., Zhao, L., Fransoo, J. J., & Woensel, v., T Tom. (2013). Sourcing strategies in supply risk management: An approximate dynamic programming approach. Computers & Operations Research, 40(5), 1371.

Gadde, L., Håkansson, H., & Persson, G. (2010). *Supply network strategies* (2nd Ed.). Chichester: Wiley.

Goddard, W. & Melville, S. (2001). Research Methodology: An Introduction (Social Research Statistics). 2nd edition. Juta Academic.

Hofmann, E., Belin, O. (2011). Supply Chain Finance Solutions: Relevance – Propositions – Market Value. Heidelberg; New York: Springer

Inventory Management Explained (David J Piasecki, 2009): A Focus on Forecasting, Lot Sizing, Safety Stock, and Ordering Systems.

Jarzabkowski, P. (2002). Strategy as practice: Recursiveness, adaptation and strategic practices-in-use. *RESEARCH PAPER SERIES-ASTON BUSINESS SCHOOL RESEARCH INSTITUTE*, (12)

Lancaster, G. (2007) Research Methods in Management. Oxford: Elsevier.

Larson, P. D., & Kulchitsky, J. D. (1998). Single sourcing and supplier certification. Industrial Marketing Management, 27(1), 73-81.

Li, C., & Debo, L. G. (2009;2008;). Second sourcing vs. sole sourcing with capacity investment and asymmetric information. Manufacturing & Service Operations Management, 11(3), 448-470.

Lyon, T. P. (2006). Does dual sourcing lower procurement costs? The Journal of Industrial Economics, 54(2), 223-252.

Mendez-Eichelmann, F. F. (2008, ). The effect of minimal attractive rate-of-return methods on load investment decisions. ProQuest Dissertations and Theses

Mishra, A. K., & Tadikamalla, P. R. (2006;2005;). Order splitting in single sourcing with scheduled-release orders. The Journal of the Operational Research Society, 57(2), 177-189.

Newman, R. G. (1989). Single sourcing: Short-term savings versus long-term problems. Journal of Purchasing & Materials Management, 25(2), 20.

Ogden, J. A. (2006). Supply base reduction: An empirical study of critical success factors. Journal of Supply Chain Management, 42(4), 29-39.

Parlour, D. (2014). *Successful outsourcing and multi-sourcing*. Burlington: Gower.

Paquette, L. (2004). The sourcing solution: A step-by-step guide to creating a successful purchasing program (1st ed.). New York: American Management Association.

Phillip J. Lederer (2009). Lead Time Performance Management

Ramsay, J., & Wilson, I. (1990). Sourcing/Contracting strategy selection. International Journal of Operations & Production Management, 10(8), 19.

Ray, P., & Jenamani, M. (2013). Sourcing under supply disruption with capacity-constrained suppliers. *Journal of Advances in Management Research*, 10(2), 192-205. Doi: 10.1108/JAMR-05-2013-0032

Ross, D. F., (2015). Distribution planning and control: Managing in the era of supply chain management. Boston, MA: Springer US. Doi: 10.1007/978-1-4899-7578-2

Seok, H., Kim, K., & Nof, S. Y. (2016). Intelligent contingent multi-sourcing model for resilient supply networks. *Expert Systems with Applications*, 51, 107-119 doi:10.1016/j.eswa.2015.12.026

Stamatis, D. H. (2012). 10 essentials for high performance quality in the 21st century (1st Ed.). Boca Raton, FL: CRC Press.

Stock, J. R., & Lambert, D. M. (2001). *Strategic logistics management* (4.th Ed.). Boston, Mass: McGraw-Hill/Irwin.

Swift, C. O. (1995). Preferences for single sourcing and supplier selection criteria. Journal of Business Research, 32(2), 105-111.

Tomlin, B. (2006). On the value of mitigation and contingency strategies for managing supply chain disruption risks. Management Science, 52(5), 639-657.

Treleven, M., & Bergman Schweikhart, S. (1988). A risk/benefit analysis of sourcing strategies: Single vs. multiple sourcing. Journal of Operations Management, 7(3), 93-114.

Van Weele, A. J. v. (2014). *Purchasing & supply chain management: Analysis, strategy, planning and practice* (5.th Ed.). Andover: Cengage Learning.

Wallén, G. (1996) Vetenskapsteori och forskningsmetodik, Second edition. Lund: Studentlitteratur AB.

Wade, W., Books24x7 (2012). Scenario planning: A field guide to the future (1st Ed.). Hoboken, New Jersey: Wiley.

Wieland, A., & Marcus Wallenburg, C. (2012). Dealing with supply chain risks. *International Journal of Physical Distribution & Logistics Management, 42*(10), 887-905.

Wynstra, F., van Weele, A., & Weggemann, M. (2001). Managing supplier involvement in product development. European Management Journal, 19(2), 157-167.

Young, R. R., Swan, P. F., Thomchick, E. A., & Ruamsook, K. (2009). Extending landed cost models to improve offshore sourcing decisions. International Journal of Physical Distribution & Logistics Management, 39(4), 320-335.

Zhaohui Zeng, A. (2000). A synthetic study of sourcing strategies. Industrial Management & Data Systems, 100(5), 219-226.

# WEB LINKS AND PRESENTATIONS

*Bansal, M. & Mathur, M. (2012). Ramping up supplier capacity in volatile times (1st Ed.). Retrieved 3 May 2016, from https://www.atkearney.com/documents/10192/575983/Ramping_Up_Supplier_Capacity_in_Volatile_Times.pdf/4c29899a-5370-4bfe-a45e-d15140ca13a7*

*What is the time-adjusted rate of return? - Questions & Answers - AccountingTools*. (2016). *Accountingtools.com*. Retrieved 28 May 2016, from http://www.accountingtools.com/questions-and-answers/what-is-the-time-adjusted-rate-of-return.html

http://www.investopedia.com/terms/l/leadtime.asp

Volvo Cars, 2016b (FY2015 presentation 2016 v1.ppt)

Volvo Cars, 2015a (purchasing presentation 2015 v1.ppt)

Picture production tooling: HLH prototypes, company website, http://www.hlhprototypes.com/production.php

Picture for flexibility and forecast error: PRESENT BY : NG SI LING B050810253 LEE WEN HAU B050810183 LIM WENG KEATB050810181 1 Suppliers Manufacturers Warehouses & Distribution Centers Customers Material Costs Transportation Costs Transportation Costs Transportation Costs Inventory Costs Manufacturing Costs http://slideplayer.com/slide/6662340/

# APPENDIX

## Appendix 1. Semi-structured Interview questions

- Brief introduction of you and your role at Volvo Cars
    - Describe yourself and your role at DM&PP
    - Who is involved in the sourcing of the community?
        - Commodity buyer?
        - How many buyers?
        - Buyers in China?

- Describe the nature of your commodity
- How do you segment your commodity?
    - Platform
        - Clusters?
        - How many sub-components
            - Is your commodity slave to other components?

- How does the product tree look like?
- How many sets of production tooling is currently used and what is the rationale behind it?
- Your business case / sourcing documentation
    - What was the decision for the sourcing of the commodity?
        - Single/Double/Triple tooling?
        - Where are the sets of production tooling geographically and why?
        - What affected the decision?

- What challenges do you see with sourcing of your commodity?
- What is your opinion on current sourcing template?