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Improving the test object process for pre-series in China

Concerning delivery precision and lead-time

Master's thesis in the Supply Chain Management program

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ABSTRACT

When Volvo Car Group is launching a new car, extensive development work has preceded the launch, in the form of so called test objects. Test object are used to; test and verify that parts and production process are of the right quality and according to a set specification. Since 2010, Volvo Car Group has expanded their business in the Chinese market and opened new facilities with the aim of making China, their second home market. Volvo Car Group has opened new plants in China, which should produce cars for the Chinese market, thus test objects needs to be built in China as well. However, still a lot of activities are carried out in Europe, and a lot of parts are sent from Europe to China operations. From previous test object builds in China it has been seen long delays, with the consequence of delayed launch for the production car. Thereby, this project aims at study how delivery precision and lead-time are built up, and potentially improved, in the test object process. What kind of activities needs to happen during the build of test objects, and what kind of activities are needed to ensure that materials are available, in time, for the test object build in China.

To conduct the thesis project both primary and secondary data has been gathered. Primary data, via interviews with around 20 different actors involved in the test object process, and secondary data from literature review and internal company documents. To treat the gathered data, Gantt-chart and process mapping has been used, in order to firstly, understand the process and conditions in which the test object process operates and secondly find risks for increased lead-time and improvement areas for reduced lead-time. Additionally, the process mapping view has its limitations and do not encompass all surrounding factors that could affect the test object process, thus an examination of these surrounding factors were made, targeted via the lens of organizational complexity.

Improvement areas for reduced lead-time and risks for increased lead-time could be identified and highlighted. To build test objects in China and sending parts over from Europe, the major barriers could be found in the lack of knowledge within the Volvo organization on how to manage the situation with difference business set-ups for Europe and China operations. A foundation for decreased lead-time in the test object process, and increased delivery quality, could be initiated by applying standardization and education, for various actors and activities in the test object process.

Key words: Product development, Volvo Car Group, lead-time reduction, material flow to China, pre-series cars in China

PREFACE AND ACKNOWLEDGEMENTS

Anders has extensive experience of working within Volvo Car Group. He has been a team leader at the assembly line in Torslanda and has got to know a lot of persons in the organization. It was thorough one of these persons the tip came that, there could be a possibility to start a master's thesis regarding the test object process for China; problems had been experienced in this process and all three of us found the topic challenging and interesting. For the reader, the authors would like to make some suggestion on how to make the read of this thesis as pleasurable as possible.

Even though, we consequently write out the abbreviations and have the abbreviation itself in brackets, to facilitate the read both for, the unfamiliar reader and Volvo personnel, we would suggest to; rip-out, copy, or print the page of abbreviations. Within Volvo Car Group, a lot of abbreviations are used, and it most likely will facilitate the read to have a separate page of those beside you as you go along, and the pages flow by. Secondly, before jumping in to chapter four and onwards, the authors suggest the reader to; take a break, fill up a fresh cup of coffee, and enjoy the continuation of the read, as we go into depth about how the purposes of the thesis will be fulfilled.

There are many people who, in different ways, have contributed to this thesis. First and foremost, we would like to thank our supervisor at Volvo, Magnus Wennström. He has supported with insight about the process, and management tips that he used in his daily work. Magnus has even taken time of his weekends to come and help clarify problems we have faced, and he brought cakes, many thanks Magnus for your valuable insight and support throughout the project work.

We would also like to thank our supervisor at Chalmers, Mats Johansson. It's been very helpful hearing Mats input from the academia point of view, making sure that meaning of, words and concepts are not misused and thoroughly explained to guide the reader, thus, help ensure the quality of the project. All luck in future supervising of master's thesis and PhDs Mats, thank you.

Of course, a big thanks goes to all the people we have interviewed within the Volvo Car Group, who devoted effort and time for our interviews. Without your input and valuable insights this thesis could not have been conducted. We have enjoyed every personal meeting, online meeting, and phone call.

Lastly, one special thanks to Niklas grandmother, who has been kind enough to lend us her car during the course of the thesis project. Countless hours have been saved compared with commuting with public transport, Thank you Gerd Axelsson.

Göteborg, June 2014
Niklas Bodestedt, Jaan Kekisev and Anders Segerlund

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ABBREVIATIONS

Abbreviation	Description
AK	Artikel-Koordinator, Article Coordinator
AVB	Analys och Verifikations Behov, Analysis and Verification Need
DP-plan	Del-Projekts plan, Part Project plan
FC	Factory Complete
IA-plan	Integrated Activity plan
IBL	In-Bound Logistics
ICO	Inter-Company Order
KU	Konstruktions Uppdrag, Construction Assignment
LSP	Logistics Service Provider
MP&L	Material Planning and Logistics, a department within Volvo Car Group
MRD	Material Required Date
MTO	Machine-Try-Out
NML	New Model Launch
PBO	Pre-Buy-Off
PD2	Pilot Plant 2, located in Shanghai
POB	Prov-Objekts Beredare, Test Object Engineer
POS	Prov-Objekt Systen, Test Object System
PVB	Prov-Vagns Beredare, Test Ojbect Engineer
PVÖ	Pilot plant in Gothenburg
QLT	Quality Leader Test Objects
SCC	Supply Chain Controller
SOP	Start Of Production
TOM	Test Object Manager
TPL	Technical Project Leader
VCCD	Volvo Cars Chengdu, production plant
VCCG	Volvo Consolidator Centre Gent
VP	Verification Prototype
VPP	Vehicle Program Plan
ZJK	Zhangjiakou engine plant

1 INTRODUCTION

In this section, the background for the thesis is presented, followed by a problem description that will lead to the purpose. Next follows, scope and assumptions that will further narrow the purpose. Lastly, an outline of the following chapters in the thesis is presented in order for the reader to get a brief overview of how the thesis structure is built up.

1.1 Background

Before Volvo Car Group launches a new car there has been an extensive amount of testing and verification done, both virtually and on physical test objects. A test object could be anything from a screw to a complete car, and during the development process of a car launch, many test objects are used. In early stages of product development, test objects normally consist of smaller sub-assemblies, not complete cars. As the product development continue, and the sub-assemblies are tested and verified separately, complete prototype cars can be assembled. Each test object, sub-assembly or complete car alike, is used to find errors and faults that can be corrected or improved, for the next test object in the product development. This goes on until the car is launched, with the right quality, cost and according to a set specification. The process responsible to meet these targets is called, the test object process. Additionally, the test object process should insure that the needed test objects are built on time, and available for testing and verification before start of production.

Volvo Car Group has been owned by the Chinese company, Zhejiang Geely holding group since 2010, and has set a goal to make China their second home market, where the company aim is to have China operations conduct their own product development, testing and verification, and production. New plants were built; pilot plant for product development, a joint venture in an engine plant, and new production plants. However, it is not yet a reality that China operations can handle the whole test object process by themselves, and European operations still does all planning and specification for the test series. Additionally, European operations support with material needs, sending over parts from Europe to China, due to the fact that local suppliers in China are not ready to supply the needed parts yet. This joint operations, between Europe and China, has had some consequences in the beginning of the cooperation, one should keep in mind that it has only been a few years with the new China business set-up. Leading to delays in the test object process, meaning; materials have not been delivered on time, and test objects have not been available for verification. Further, since it is a fairly new business set-up, new problem surfaces which have not been dealt with before and adds additional risks of increased lead-time in the test object process. This is what this thesis aims to understand, how does the business set-up with China operations work, what are the risks of increased lead-time, and where improvements can be made in the test object process for China.

1.1.1 Volvo Car Group

For the unfamiliar reader, Volvo Car Group is a global car manufacturer founded in Sweden 1927 with about 23 200 employees, Volvo AB was initially a supplement to a Swedish bearing company called SKF. During the 21st century Volvo cars have had several owners, such as Ford and General Motors but has since 2010 been owned by, Zhejiang Geely holding group. A Chinese owner that has allowed Volvo to work more autonomously then previously mentioned owners. The headquarters of Volvo Car Group is still situated in Torslanda, Sweden where the main product development is also situated. Production is done in; Sweden, Belgium, Malaysia, and China, where Volvo Car Group produces cars that range from, small family cars to Suburban Utilities Vehicles (SUVs) and the biggest market is in Europe (52,9%). For more company facts, see table 1.

Table 1 - Volvo Car Group; company facts.

Company Facts	
Owner:	Zhejiang Geely holding group since 2010
Number of employees (2013):	23 200 persons - 1438 in China - 15753 in Sweden - 6009 in other countries
Number of sold cars (2013):	427 840 in about 100 countries world wide ~1-2 % of world market
Market splits:	-EU20 52,9 % -China 14,3 % -North America 14,3% -Rest of the world 18,5%

Volvo Car Group has ambitious expansion plans, with the aim of selling over 800 000 cars by 2020, and part of that plant encompasses making China their second home market. In the light of that expansion plan, Volvo has, since 2011, built a new pilot plant in Shanghai, and two production plants in Chengdu, and Daiqing. Where the later has not have not yet started production, and Chengdu has been production on full speed since the 4th quarter of 2013. Additionally, an engine plant in Zhangjiakou is partly owned by Volvo Car Group, supplying engines for the China market.

A decision has been made, by the owners of Volvo Car Group, to treat Volvo European operations and China operations separate. Creating two entities, with the goal of having the entities manage and doing development work separately. Even though, that decision has been made, it is not yet the reality. The European business set-up and systems, were directly put into the new plants in China, with many Europeans to support in the transition. This transition is not yet over, and the European operations support the China operations, both with knowledge, resources, and parts that cannot be supplied from local suppliers in China.

1.1.2 The test object process

This thesis is conducted under the department of *Test object and vehicle handling*, which in turn is a sub-department under R&D. This section will explain what the test object process encompasses, what phases the test object process goes through, what are test series, and which locations are of interest in this thesis.

The test object process runs through all units within R&D as well as Material Planning & Logistics, Purchasing, and Manufacturing. The process has close boarder lines to many other processes, and contains five main phases; Planning, Specification, Material Procurement, Build, and Vehicle Management (Test Object Process Self-Study Material, 2011). Below, in figure 1, these phases are showed, and to repeat, a test object could be anything from a screw to a complete car.

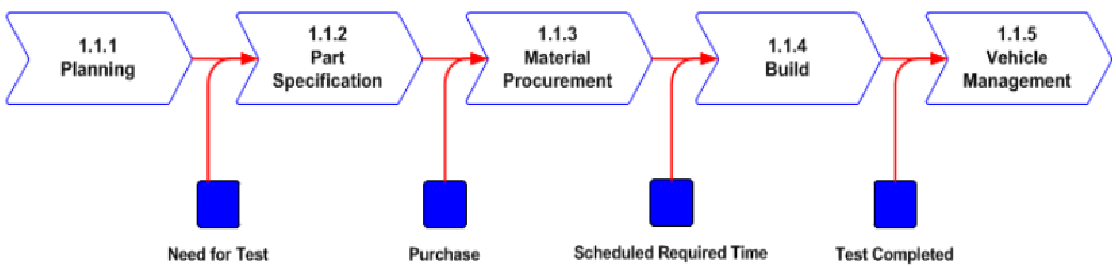

Figure 1 - The test object process within Volvo Car Group

Test object are used to test and verify that; parts, sub-assemblies, and complete cars have the correct quality, are according to a set specification, and can be built together in the production plants for mass production. In the *planning* phase, the need of test object is created and received to a function called: analysis and verification need. Material Requirement Dates (MRDs) are set, deciding when materials are needed at different facilities in order to start the build of test objects. Additionally, a build strategy is decided upon, making sure that test objects are built on time. *Part specification*, is when part information are entered in Volvo test object system. *Material procurement* encompasses activities such as; purchase orders and the physical flow of materials. The *build* phase is the actual build of test objects. Finally, the *vehicle management* is activities that relates to handling of test object when all tests and verification has been done. The test object process is iterative, and will start over each time a new test object should be built, or changes occur within the process. An important thing to point out is that, the test object material flow are characterized by small lot-sized, unpredictable demand, and is not prioritized compared with the considerable larger flow of materials for the production cars.

In Volvo Cars, product development may contain up-to seven main stages before a launch of a new car. These stages are called test series, and in turn the test series contains a lot of test objects.

After each main stage, or test series, the test objects are tested and verified, and if faults are found, they will be corrected and updated in the next coming test series. Since a complete car consists of thousands and thousands of parts, this iterative approach is necessary to ensure that the final car will not have any faults when it is launched in mass production. In figure 2, the different denotations for the seven test series can be seen, and in table 2 a brief explanation of the denotations and the purposes can be found. In general, as you move from left to right in the figure, the closer you come to mass production. How many of these test series that are used will depend on the extent of a new product development project. E.g. when launching a completely new car model all test series have to be used, but if it is some updates on an existing car model, then some of the test series to the left in figure 2 may not be necessary. An important distinction should be made between, “product development prototype series” and “pre-series built in target factory”. The latter are, complete cars built in the production plant that will mass produce the car after it is launched, and the former are sub-assemblies built in pilot plants.

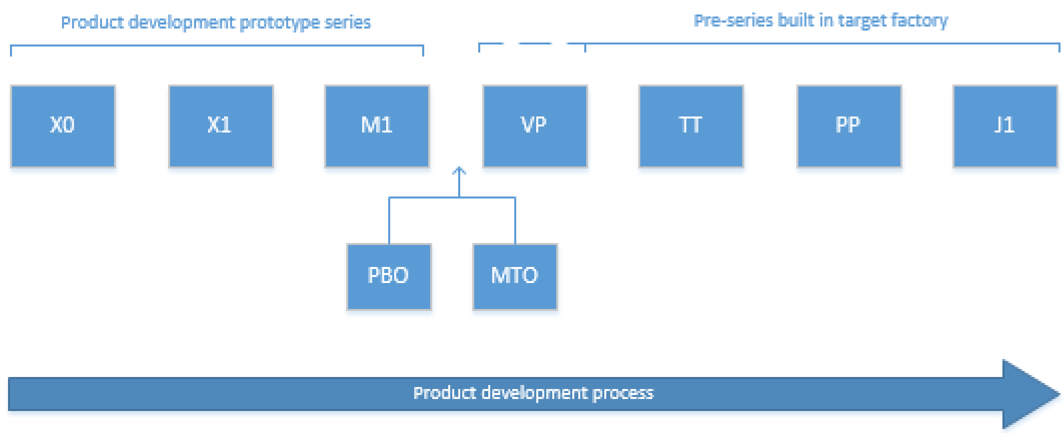

Figure 2 - Different test series within product development in Volvo Car Group

Figure 2 also shows the processes of Pre-Buy-Off (PBO) and Machine Try-Out (MTO). These are not main test series, but important processes that are needed to support the build of test objects. In many new product development projects, new tooling is required in the production plants, tooling such as; stamps, lifting devices, welding robots or rigs. The Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) process are tooling tests, making sure that needed tooling produce according to specification, and that the production process works before launch of a new car. More precise, the Pre-Buy-Off (PBO) process is a “Vendor Tool try-Out”, a tooling try-out at the supplier site, and the Machine-try-Out (MTO) process is a Tool Try-Out at the production plant that shall mass produce the car after launch.

Table 2 - Explanation of; denotation, purpose and decisions of each main test series during product development

Series	Explanation	Purpose	Decisions
X0	**Xperimental 0**. System development in rig for power train.	Secure that X0 test object can support testing objectives.	Can the test object be used for: • Computer aided engineering model correlation • Development support
X1	**Xperimental 1**. System development in drivable mule for power train.	Secure that X1 test object can support testing objectives.	Can the test object be used for: • Computer aided engineering model correlation • Development support
M1	**Mechanical**. A verification prototype for the under body.	Secure that M1 test object can support verification of the under body design.	Decide if the test object can be used for under body verification.
VP	**Verification Prototype**. A complete car, under and upper body. With parts from the correct suppliers.	Secure that VP-series can be used to verify Production Intent for the complete vehicle.	Decide if the test object can be used for complete vehicle verification.
TT	**Tooling Trial**. First pre-series build in the target factory with correct tooling and parts.	Secure that the TT-building meets the targets for the program.	• Confirm process capability • Confirm education of production personnel
PP	**Pilot Production**. Final pre-series build in production-like conditions. More cars are built then in TT.	Secure that the PP-building meets the targets for the program.	• Confirm process capability • Confirm education of production personnel
J1	**Job 1**. Final confirmation of product quality and volume. Ramp-up to full production speed	Secure quality and volume targets in production conditions.	Can the cars be built with: • Quality according to plan • Speed according to plan

In this thesis, when talking about building test object in China, the locations of interest are; the production plant in Chengdu, the pilot plant in Shanghai, R&D department in Gothenburg, a consolidator centre in Gent, and a Know-Down facility in Maastricht. The authors will briefly explain what they are, and why they are important in the context of building test objects in China.

The Chengdu production plant is a newly built production plant that will produce cars for the Chinese market. Chengdu will produce the complete car after it is launched, therefore, all test series to the right of Mechanical 1 (M1) in figure 2, has to be built in Chengdu in order to verify both the car itself but also that the production process works. The pilot plant in Shanghai has their own product development department, but not yet with the same capabilities as in Europe. When building test objects in China, the pilot plant in Shanghai is responsible for all tests of software, which will be downloaded into the complete cars later in Chengdu production plant. The R&D department in Gothenburg is responsible for the first two phases in the test object process, namely, planning and specification. Thus, the R&D department in Gothenburg has considerable impact on the test object builds in China. Volvo has set-up a consolidator in Gent, through which the main material flow to China goes. If the facilities in China want parts from Europe, suppliers should, as a standard, send parts through the consolidator in Gent. Finally, a Knock-Down facility in Maastricht, Netherlands, is also involved in the material flow to China. First off, a Knock-Down facility is basically a kitting supplier or consolidator, with its own part storage. The facilities receive order-lists and kit accordingly, they pick part either from their own storage or send out call-offs to suppliers located in Europe. More specifically, Maastricht main responsibility is to support with production parts for other Volvo assembly and production plants in; Malaysia, Daiqing, Chongqing. But in some cases Maastricht has to send parts to the production plant in Chengdu and thus, it is an option to use the facility in Maastricht to send parts for the test object process in China.

1.2 Problem description

First off, doing business with China is hard, tax and customs regulations are very strict and tend to change quite arbitrary. Thus, the decision of making China operations responsible to manage themselves as a separate entity seems a good idea, because it is easier within the country, and local employees understand the China business environment better. However, since European operations still are involved to a big extent, knowledge and skills about China operations, needs to be obtained in the European organization. In other words, the business set-up for China needs to be understood, in order for European operations to carry out their work and support with sending parts to China for test series. As it is seen today, this knowledge and skills build up is lacking, which could have consequences on the lead-time for the test object process. E.g. it is European operations that are responsible for all planning activities when a new project should start, and if the actors in Europe do not have the knowledge or skills about the China set-up, plans could be done according to the familiar European set-up, and thus not considering possible differences that the China set-up might cause.

More specifically, there were problems with delayed test objects, for the car that is now in production in Chengdu, an extended Volvo S60. Additionally to delays in the test objects, extra resources in terms of man hours had to be put in to solve problems that surfaced, problems that had not been seen before, since the business set-up in China is rather new. One problem that surfaced was the difference in, what Volvo labels, build logic for the Verification Prototype (VP) series. The Verification Prototype (VP) series is the first time in the development process that a complete test car is built, see figure 2, thus some kind of plan needs to be made as to how the car should be built. This plan is the, so-called build logic for the Verification Prototype (VP), that describes which activities need to happen before another activity could start, and how long time does the activities take. This build logic is shown in a plan that Volvo calls Integrated Activity plan (IA-plan). The problem however, is that this build logic has not been adjusted to the conditions in China yet, the planning function in Europe uses the build logic developed for Europe and consequences could be late deliveries of test object, if the plan developed in Europe does not reflect the reality in China. The most critical outcome from the build logic, i.e. the Integrated Activity plan (IA-plan) is that Material Requirement Dates (MRDs) can be derived, meaning the point in time when materials need to be at different facilities, in order to start the build of the test object. Thus, if the plan in Europe does not reflect the real conditions for the build in China, the Material Requirement Dates (MRDs) could be incorrect and there is no way that a test series could be built on time. Moreover, the Material Requirement Dates (MRDs) are the joint planning point for all actors and functions within the test object process, hence if those Dates are wrong the whole test object process will be managed under incorrect conditions.

If however, the assumption is made that these Material Requirement Dates (MRDs) are set correctly, there were still other problems causing delays for the car that is now in production in Chengdu. E.g. the process of Pre-Buy-Off (PBO) and Machine-Try-Out (MTO), tooling try-outs at supplier site and production site, were about 2 months delayed, and since the tooling is needed in the production plant in Chengdu before the build of the Verification Prototype (VP) can start, delays in the Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) have a high risk of increased lead-time for the Verification Prototype (VP) series. One reason for the delay in the Pre-Buy-Off (PBO) could be found in the readiness of local suppliers in China. The tooling suppliers in China need test material in order to verify if, their developed tools are producing according to specification set by Volvo Car Corporation. Local suppliers in China were not ready to produce this test material yet, simply because they had not produced these parts before and were not ready in time for the Pre-Buy-Off (PBO) process. Thus, these test materials had to be supported from suppliers in Europe, with a number of problems caused by the fact that European operations were inexperienced on how to manage these extra support material from Europe to China. There are few standard processes in this flow with a lot of manual labour without system support, and risks of extra transports, with increased lead-time as a possible consequence.

1.3 Purpose

Drawn from the background and the problem description, the purpose of the master thesis is divided in two parts;

1. Analyse the current Verification Prototype (VP) build logic for Shanghai pilot plant (PD2), Chengdu production plant (VCCD) and Zhangjiakou engine plant (ZJK) and propose solutions on how to improve the process in terms of delivery precision for the material.

2. Analyse the process of getting materials for Pre-Buy-Off (PBO), Machine-Try-Out (MTO) and Verification Prototype (VP) series in China and identify risks of increased lead-time and highlight improvement areas for lead-time reduction from the creation of verification & test need to parts in goods receiving.

1.4 Scope and Assumptions

The section will outline what the project will focus on and consequently what will not be dealt with in this thesis.

- *The proposed solutions for the Verification Prototype (VP) build logic does not consider potential reduction of costs or implementing cost, the proposed solutions should be seen as suggestions to further investigate and created a business case around.*

- *The master´s thesis will only focus on the test series Pre-Buy-Off (PBO), Machine-try-Out (MTO) and Verification Prototype (VP). See figure 3.*

  The Verification Prototype (VP) series is the first time when a completely test car is built, which makes it an critical phase in the product development, Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) are prerequisites to be able to build the Verification Prototype in China.

- *The master´s thesis will only consider parts that are available in European production and transported to China.*

  Production parts that are available in European production cars can be supplied from Europe to China.

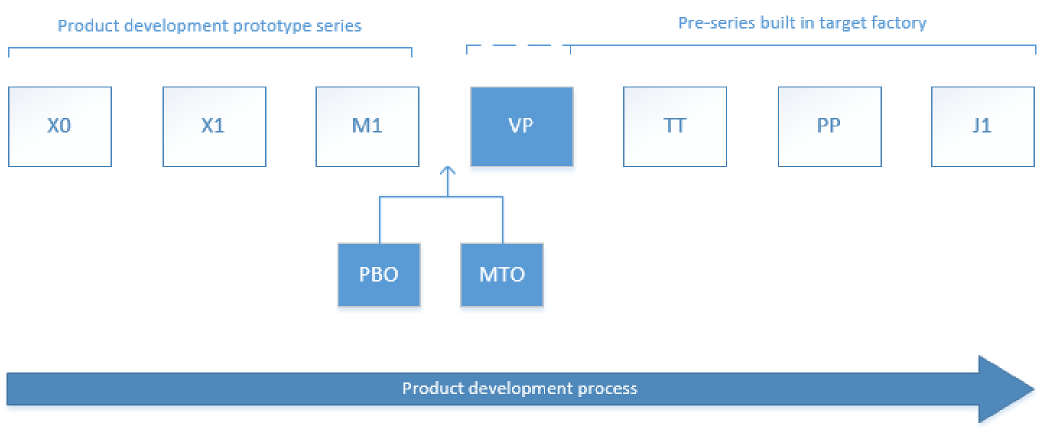

Figure 3 - Highlighted test series, in scope for this thesis

Assumptions

The test object process is characterized by variation, uncertainty, and changing conditions, therefore three important assumptions has been made, in order in order to delimit the work to a manageable workload and ensure that the project can finish on time. The assumptions have been made in dialogue with the company supervisor, to secure that assumptions made does sufficiently correlate with the real environment in which Volvo operates.

- *An assumption has been made that for Machine-Try-Out (MTO) and Verification Prototype (VP) series, correct production suppliers are ready to supply parts.*

  This means that, purchase orders are ready and that normal factory systems can be used to handle, delivery plans and call-offs automatically.

- *An assumption has been made that for Pre-Buy-Off (PBO) series, correct production suppliers are not ready supply parts.*

  This means that, supplier that should supply the parts for the Verification Prototype (VP) series are not ready in the point in time of the Pre-Buy-Off (PBO) process, and European suppliers has to support with material in the meantime.

- *An assumption has been made that, late changes in product development i.e. late drawing changes from engineers, does not affect parts that are in production in Europe.*

  The assumption mean that, production parts do not tend to change that often, and when they do it can be planned without risk of increased lead-time. Thus, late changes from engineers do not affect the lead-time.

1.5 Outline

After the introduction the first chapter presented is a **frame of reference chapter**, where some relevant literature is briefly introduced. The goal of this section is to present a broader perspective of the study area and help to define what needs to be investigated in order to fulfil the research purposes. Firstly, product development concept is targeted followed by the discussion of lead-time reduction. Thereafter, a discussion about process perspective and organizational perspective regarding lead-time is introduced. Lastly, the concept of risk is elaborated.

Following the literature review is a **methodology chapter**, how have the thesis been conducted via a description of a research model. Discussion about data collection methods follows, encompassing literature review, company internal document review and interviews. After that, data treatment methods are introduced and the chapter will end with a discussion about quality of data from the reliability and validity perspective

Succeeding the methodology, a chapter called: "**Verification Prototype build logic in China**" will be presented; the chapter targets purpose 1 of the thesis. The goal is to derive Material Requirement Dates, and important activities that are needed as input to the second purpose of the thesis. The Chapter will firstly, on a general level describe; what does the Verification Prototype build logic mean, and how does it relate to the test object process. Secondly, the created Verification Prototype build logic for China is presented, showing the current situation in the form of an Integrated Activity plan (IA-plan) template. Lastly, discussion regarding the differences and connections between plans will be presented.

In the fifth chapter, which is called "**Process of getting materials from Europe to China**", input will be taken from chapter four, in order to find risks of increased lead-time, and improvement areas for reducing the lead-time, from a process view perspective. Firstly, a description of Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) series is provided following with an aggregated activity and lead-time test object process maps. Thereafter, more specific current state process maps are presented. The chapter ends with a discussion about identified risks of increased lead-time, and improvement areas for reducing lead-time.

Following the process view, the other aspect of lead-time from the research model is presented, namely **organizational view of getting materials from Europe to China**. The organizational view is looked upon from the perspective of complexity. Firstly, empirical findings from interviews with various people who are directly or indirectly are connected with the test object process. Secondly, the complexity drivers are described and discussed in the context of Volvo Car Group. Thirdly, possible improvement areas of; supply chain visibility, cross-functional teams and front loading are introduced and discussed. The chapter ends with a discussion how these concepts can be used to deal with the defined complexity drivers.

The seventh chapter will **combine the process and organizational** view, by taking together the key findings from both perspectives, and providing a joint discussion over the risks of increased lead-time and improvement areas for reduction of lead-time.

The thesis will end with a **conclusion**, where the answers to the two purposes will be restated.

2 FRAME OF REFERENCE

In this section, relevant literature is briefly introduced. The goal of this section is to present a broader perspective of the study area and help to define what needs to be investigated in order to fulfil the research purposes. Firstly, product development concept is targeted followed by the discussion of lead-time reduction. Thereafter, a discussion about process perspective and organizational perspective regarding lead-time is introduced. Lastly, the concept of risk is elaborated.

2.1 Product Development

When looking into how different authors define research and development (R&D), it can be seen that often it is separated in to two concepts; research and development (Wheelwright and Clark, 1992; Sheasley, 2000). For example Sheasley (2000) define research as the process of acquiring new knowledge and building up the technology base, while development side is the process of making use of that knowledge and combining it with appropriate market intelligence to design and develop new products. This thesis focuses on the test object process, which purpose is defined by Volvo Car Group as: "providing test objects for testing and verification before start of production. The focus is to support the delivery of test objects on time, with correct cost and according to the specification" (Test Object Process Self-Study Material, 2011). Therefore, the test object process is dealing with production of all verifiable test objects; hence, the scope of the thesis lies in the development side of R&D.

Similarly to Sheasley (2000), Krishnan and Ulrich (2001) define product development as the transformation of a market opportunity and a set of assumptions about product technology into a commercial product. Karlsson (2004) make an effort to describe the development side in more depth. They state that the development process has a clear end date; thus, the time horizon is set and in the end, the product has to be in finished state. The organization of a development process is usually product oriented and various departments are involved; therefore, cross-functional teams are common practice (Karlsson, 2004). This also means that there is a big need for knowledge and competence to successfully carry out the process, since many functions are involved. It can be concluded from Karlsson (2004), that the focus of development is on a specific product with clear deadlines.

2.2 Lead-time reduction in product development

The existence of clear deadlines brings us to the issue of the length of the lead-time in product development. As it can be seen, then companies and academia are putting a lot of effort in to finding ways how to reduce the lead-time of product development (Karagozoglu and Brown, 1993; Bartezzaghi et al., 1994; Johnson and Brockman, 1996; Jun et al., 2006; Persson et al., 2006). One might start to wonder, what the motivation of having shorter lead-time is. Persson et al. (2006) state that the ability to continuously develop new products is vital to any technology-based company, and moreover, the ability to deliver those new products to the market on time is one of the key competitive advantages. Karagozoglu and Brown (1993) are explaining that faster product development times mean that higher profitability can be reached through extending a product's sales lifecycle, providing opportunity to charge a premium price, and allowing temporary monopoly advantages. Shorter lead-times will increase the opportunity to gain from the evolution of markets, technology and regulations, since, it will be possible to react to those changes faster.

Persson et al. (2006) looked into Swedish manufacturing companies and identified what has happened between the years 1991 to 2004 in the product development lead-time progress. Interestingly, even though companies have been able to slightly shorten the project times, then companies suffer under the same amount of prolonged projects as in past. It was found that 60% of all development projects were late 30% on average. Therefore, good project management still stays critical. Persson et al. (2006) also concluded that there is no magical recipe and companies have to carefully adopt practices that are helpful in their situation.

Persson et al. (2006) brought in another idea, that the lack of progress over years might be because of gradual increase of complexity in the development process, therefore making it increasingly harder to manage the process and predict lead-times. Jun et al. (2006) are also bringing up the issue of complexity in a product development process, by stating that because of the increase in complexity level, it is increasingly important to manage the process in time perspective. According to Jun et al. (2006) the complexity is generated due to a large number of decision-making activities encompassing creative thinking, experience, intuition, and quantitative analysis. Due to a large number of decision-making activities, product development can be characterized by words like iterative, cooperative, evolutionary and uncertain. To manage the lead-time, it is needed to understand and measure the lead-time, but according to Jun et al. (2006) complexity makes it very hard to measure the lead-time.

Bartezzaghi et al. (1994) defines the meaning of time concept as a resource consumed by the process. According to this approach, lead-time is computed from the start of first activity of the process to the delivery of the output. Thus, lead-time is strictly depending on the identification and definition of the process. Therefore, in order to fully and correctly understand the lead-time, it is needed to understand the process. Next to merely understanding the lead-time, understanding the process is crucially important for finding the right improvement areas to enhance the product development process (Johnson and Brockman, 1996). As Johnson and Brockman (1996) motivate, only one designer's perception of bottlenecks cannot be fully trusted when trying to improve the product development process. It can lead to little or no improvements at a high cost. Therefore, creating process understanding, for example through process mapping, is very important.

Next to importance of process approach, many authors reflect to general issues that are either directly or indirectly increasing the lead-time of product development. To bring in some examples, Tidd et al. (2005) argue that cooperative teams and group interaction within the organization is important for efficient development process. Having an appropriate organizational structure and culture is important to be successful in product development. Next to that Ancona et al. (2002) express that to be successful, departments have to collect and share information and resources from and to a variety of sources, which means that failing to do so will lead to longer lead-times. Also, these necessary flows between different entities will make the whole process more complex and harder to manage. These issues need to be targeted as well, to understand the risks of increased lead-time and identify the improvement areas for reduced lead-time.

Bartezzaghi et al. (1994) take those ideas presented above together with dividing the two key issues that need to be addressed while working with lead-time reduction in product development. According to Bartezzaghi et al. (1994) one needs to address:

1. Process understanding through lead-time modelling to map down what makes up the total lead-time in a given process. This means identifying the basic time components and how they are related to each other.
2. The structural and managerial factors and mechanism which affect the time components of total lead-time. These can be seen as direct and indirect lead-time drivers.

To summarize this approach, it can be said that two perspectives should be in focus – the specific process view and the general organizational view. This concept how to deal with lead-time reduction is illustrated in figure 4.

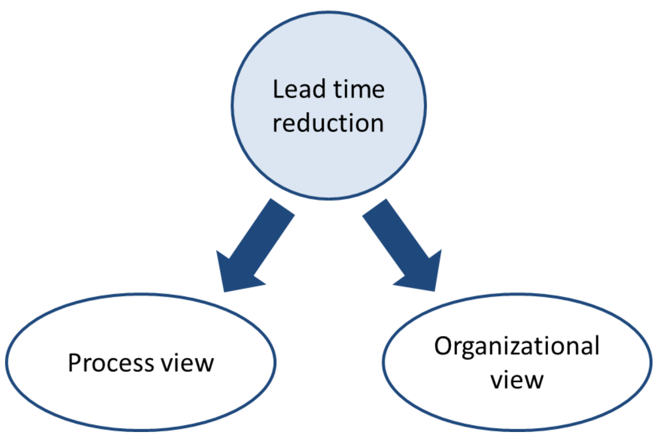

Figure 4 - Approach to lead-time reduction

One way to understand the above approach is to see process view as more specific identification what activities are building up the lead-time, who are involved in those activities and how these activities relate to each other. Basically, the important thing is to first map down the current situation of lead-time components and their laws to find possibilities for improvement. The organizational view, on the other hand, will give the opportunity to identify issues that will not be targeted by process view, but are directly or indirectly adding to lead-time. Double approach will minimize the risk of missing important issues and providing a comprehensive approach. While there are many authors talking about process view and especially process mapping, then it is somewhat harder to find good model for targeting organizational approach. The authors have chosen to use *Event-driven Process Chain modelling (EPC modelling)* as a method to target the process view, since it provides an understandable and logical overview of the activities and resources and their relations in processes. Davis (2001) defines EPC as a "dynamic model that brings together the static resources of the business (systems, organisations, data, etc.) and organises them to deliver a sequence of tasks or activities ("the process") that adds business value. This method will be discussed in more detail in the methodology chapter, but the way how to target the organizational view has to be discussed further. The next section will provide a motivation to use complexity management as basis for targeting organizational approach.

2.2.1 Complexity

Perona and Miragliotta (2002) state that because of innovation, globalization of markets and increasingly demanding customers, companies have to supply a growing mix of products with higher customization opportunities to the customers. This leads to increasing complexity because of wider product variety, smaller production lot sizes, and more actors to co-ordinate within the supply chain (Perona and Miragliotta, 2002), and successful are the companies who are able to cope with these changing conditions. Especially apparent in Volvo Car Group is the increase of actors to coordinate, since Geely took over ownership and expanded the business in China. Additionally, the test object material flow are characterized by small lot-sizes which according to Perona and Miragliotta (2002) increases the complexity in the supply chain.

Complexity has been already mentioned couple of times above when describing the product development process. It is evident that the level of complexity in development processes is increasing over time (Persson et al. 2006; Jun et al. 2006), especially when technology and products are getting more and more complex in time. According to Costa et al. (2012), the product development process has a high level of uncertainties and risks, and need to manage a high amount of knowledge and information. These factors make the process very complex and it is argued by Serdarasan (2013) that although there are certain difficulties in dealing with complexity in the supply chain, numerous studies support that managing complexity leads to better supply chain performance, which will result in reduction of lead-time. Volvo Cars is facing similar challenges regarding the complexity that is driven both, by the changing market trends, and the internal product development process. Hence, it is fair to assume that complexity plays big role in adding up lead-time to the development process and when the complexity issues are targeted in a successful way, then ultimately lead-time will be reduced. Additionally, according to Perona and Miragliotta (2002), control and management of the increasing level of complexity is a strategic issue for companies. This gives the motivation to the researchers to use the concept of complexity as a guide to approach the organizational view. This means that complexity drivers need to be identified and studied in the company specific context. It must be mentioned, of course, that this is one of many possible approaches how to target the organizational view.

In order to evaluate complexity, the term complexity has to be defined. The term complexity has a definition and meaning for most people but it is still hard to define explicitly. From the academia point of view, very few authors have addresses the topic, and when it is addressed there still seem to exist ambiguity perceptions of the term. A problem with defining complexity stems from the issues regarding where to define the complexity boundaries, as it is always possible to add a new level of detail in the system studied (Perona and Miragliotta, 2002). The term complexity does not mean the opposite to simplicity; neither is it a synonym to complicacy. The word complexity originally means “things which interacts with each other”, and from a manufacturing point of view complexity is created due to variety within the boundaries of its supply chain.

The drivers of complexity are to a large extent driven by context variables (Waidringer, 2001; Perona and Miragliotta, 2002). The researchers try to provide a graspable model of complexity to help the practitioners at Volvo to understand the nature of complexity and how to work with it. The scope of the introduced complexity drivers below will therefore, only be limited to the most relevant drivers in the context at Volvo. These drivers are; variety/uncertainty, number of communication channels, strategic objectives and ignorance. These complexity drivers are later analysed and discussed in detail in the context of Volvo Cars in chapter 6.

Variety/uncertainty is a well-known driver of complexity, although different authors have different interpretation of what variety mean. The term variety, in this context, refers to changing conditions and difficulties with coordination of activities (Perona and Miragliotta, 2002). According to Waidringer (2001), the relation between variety and complexity is that; variety stirs up new conditions in the organization, and organizations ability to adapt and deal with the new conditions will determine the organizations success or fail in dealing with complexity. This also implies that variety is closely related to uncertainty. Variety can involve different aspects such as, variety in number of different products, distribution channels, methods, suppliers, demand, interactions, relations, processes etc. An increased degree of variety in these areas increases the need for coordination, which indeed is problematic and increases the risk of amplified cost and lead-time.

Communication channels refer to the number of possible channels how individuals could gather or forward information. Communication channels in this sense, does not refer to the mode of communication such as mail, phone, or intranet. Instead, communication channels refer to the number of possible interactions. The problem with a high number of information channels is that it may increase the number of assumptions and thereby, add up to an increased risk for ambiguous decisions. The structure of information and communication is adding on to a high level of complexity, as the amount, accuracy, and reliability of information are affected. A high number of possible interactions make the system hard to predict, when the whole or parts of the organizations may respond differently, due to the various kinds of interconnections (Caridi et al., 2010; Bozarth et al., 2009). As a matter of fact; a high degree of communication channels can be inevitable for processing tacit knowledge or information for solving direct problems that may occurs e.g. between two members in a project belonging to different departments (Thomke and Fujimoto, 2000). On the other hand, if there are lacking standards on how to use the channels, then high number of channels could backfire the system. Vital for the communication is to strive for joint communication that penetrates all the involved departments and clearly reaches all the involved members.

Any department within an organization is characterized by some *strategic objectives* (Perona and Miragliotta, 2002). In addition to the different strategic objective, different department may have different operational objectives that may originate from the different context they operate in and what kind of information they have received. Waidringer (2001) argues that different objectives will make a stakeholder adhere to the best and most favourable way when conditions change. An example of this can be, when two different departments that are involved in a joint task, respond differently to the same information, as they have different objectives and thus, will use the given information differently. Therefore, different strategic objectives can be one complexity driver.

Lastly, *ignorance* can be considered as a complexity driver. Ignorance refers to the ability to understand the features of the system or its boundary conditions. The relation to objectives stems from the fact that decisions in one department may change conditions for another department. This may not always be visible for the first department as ripple effects to other departments may be out of the span of attention. According to Waidringer (2001), the aspect of ignorance is two-folded: (1) how you understand the system; (2) how you understand what impact your decisions will have on other departments.

These four aspects of complexity will be used to analyse the company to provide the organizational view, to find risks of increased lead-time and improvement areas to reduction of lead-time. The complexity drivers will be taken under examination in chapter six, where organizational view of the process of getting materials from Europe to China is investigated.

2.3 Risk of increased lead-time

As it is stated in the purpose, one aim of the thesis is to identify risks of increased lead-time. In order to do so, it is important to define what is meant by risks. Jereb et al. (2012) come to a conclusion that there are countless conceptions and definitions of the term risk. In a situation, where numerous interpretations exist, it is very important to provide a definition, which is used in the thesis. According to ISO 31000:2009 standard, risk is defined as "effect of uncertainty on objectives". They further state that uncertainty arises from internal and external factors, which makes it hard for the organization to control if their objectives are achieved or delivered on time (ISO, 2009). Purdy (2010) discusses that ISO 31000:2009 definition creates a new mind-set, which shifts the emphasis from the possibility of an event happening to the possibility of an effect and, in particular, an effect on objectives. Purdy (2010) further argues that with this definition, the risks are not merely events or consequences; they are descriptions what it could lead to, in terms of how objectives could be affected.

To summarize the discussion above, risk definition has two key components that can be elaborated in the thesis context; effect of uncertainty and the objective that this effect can influence. Firstly, the objective that is under investigation is the Volvo Cars goal to make sure that test objects are built on time. The effect of uncertainty in this thesis is considered to be the increased lead-time. Therefore, in this thesis, risks are treated as events or consequences that have an effect of increasing lead-time, which will jeopardise the possibility to meet the objective of building the test objects on time.

2.4 Summary of the frame of reference

Firstly, product development environment was briefly introduced and it was noted that product development projects have clear deadlines. Therefore, the projects have a lead-time while they are carried out. Also, it was found that it is beneficial to have shorter lead-times; hence, lead-time reduction in product development projects is a meaningful goal to strive towards. One possible way how to target the aim of lead-time reduction in product development is to create a process understanding through process modelling and create understanding of the structural and managerial factors and mechanism, which affect the components of lead-time as well. This approach is taken under use to conduct the study. In the process view, a thorough understanding of activities and their relations are created. This will lead to the possibility of finding risks, weak points, and ultimately improvement areas, what could be done in order to affect the lead-time positively. As there might be other factors that directly or indirectly affect the lead time, which will not be found through process analysis, then organizational view is used to provide a more complete picture. Since, it was concluded that there exists high amount of complexity in product development process and complexity is a driver of lead-time, then concept of complexity was chosen to structure the organizational approach. Key complexity drivers were identified through literature, which will be used as guidelines to analyse the test object process in Volvo.

Lastly, risks were defined as events or consequences that have an effect of increasing lead-time, which will jeopardise the possibility to meet the objective of building the test objects on time.

3 METHODOLOGY

In this section, the research model implemented is described. Discussion about data collection methods follows, encompassing literature review, company internal document review and interviews. After that data treatment methods are introduced and the chapter will end with a discussion about quality of data from the reliability and validity perspective.

3.1 Research model

The research model is presented to illustrate what is done during the thesis project, in order to reach the deliverables, which would fulfil the research purposes. Also, the model shows how the two purposes are linked and why it is necessary to target purpose 1 before purpose 2. The research model can be seen in figure 5 and it will be explained in detail below.

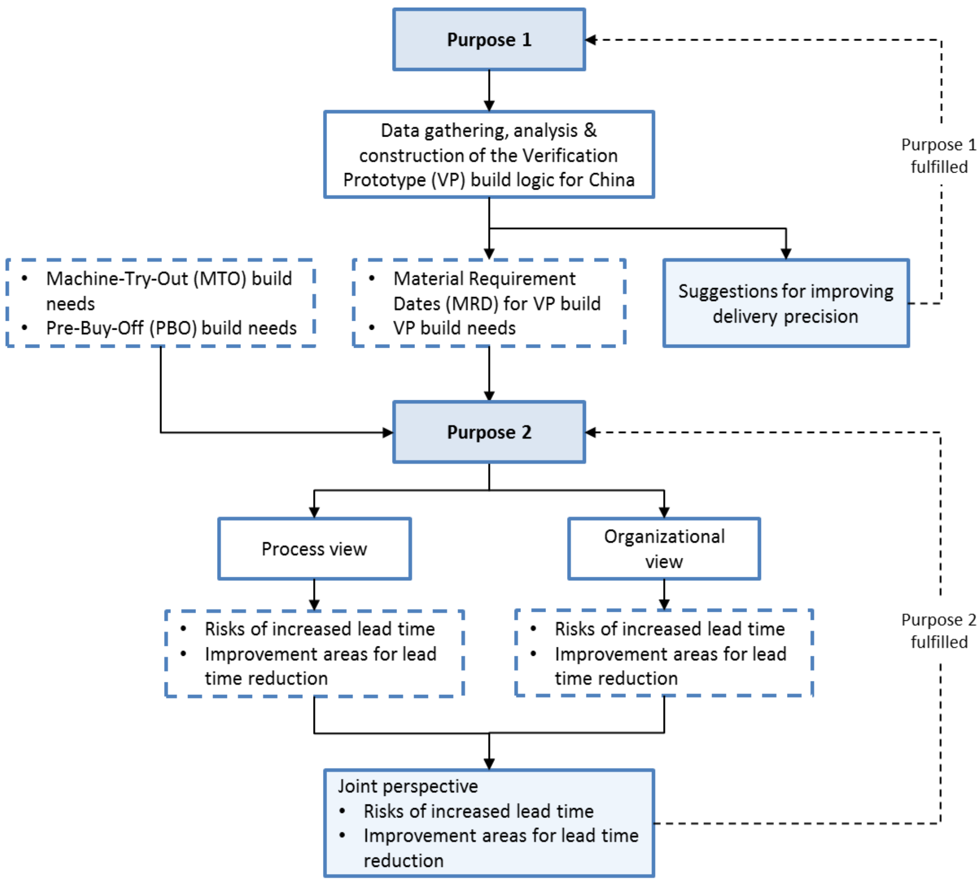

Figure 5 – Research model

Firstly, purpose one "*Analyse the current Verification Prototype (VP) build logic for Shanghai pilot plant (PD2), Chengdu production plant (VCCD) and Zhangjiakou engine plant (ZJK) and propose solutions on how to improve the logic in terms of delivery precision for the material*" is targeted. To do so, data will be gathered, mainly through interviews, about different activities, that are needed to be done, to successfully build a Verification Prototype (VP) test object in

China. Also, the average durations of the activities, as well as the logical dependencies between the activities are investigated. This information will be gathered from actors whose task is to perform different activities in Verification Prototype (VP) build, hence, actors in China. If all needed information is gathered, then the activities will be linked together through connecting them with identified logical dependencies in order to form a Gantt chart. Gantt chart will provide visualisation of the build logic and will help in the analysis phase. When the logic is defined, then it is possible to analyse it and propose solutions on how to improve the logic in terms of delivery precision for material.

Purpose two states "*Analyse the process of getting materials for Pre-Buy-Off (PBO), Machine-Try-Out (MTO) and Verification Prototype (VP) series in China and identify risks of increased lead-time and highlight improvement areas for lead-time reduction from the creation of verification & test need to parts in goods receiving"*. It has to be pointed out, that in order to start working with purpose two, then the times when the parts are needed in goods receiving have to be understood. During the fulfilment of purpose one, correct Material Requirement Dates (MRDs) will be identified for Verification Prototype (VP) build. Also, the work done will provide the researchers understanding of Verification Prototype (VP) series build needs. Therefore, it is not possible to start working with purpose two before purpose one is fulfilled.

Additionally to the Material Requirement Dates (MRDs), an understanding of the build needs for the Machine-Try-Out (MTO) and Pre-Buy-Off (PBO) series will be presented, before targeting purpose two. When the necessary background is understood, then it is possible to start working with purpose two. The process of getting materials for Pre-Buy-Off (PBO), Machine-Try-Out (MTO) and Verification Prototype (VP) series in China is looked from two perspectives – process view and organizational view. This approach is stated in the theoretical framework and the goal with both views is to identify risks of increased lead-time and highlight improvement areas for lead-time reduction. The process view is conducted mainly through process modelling and analysis and the organizational view is approached using the concept of complexity. Both views will provide an understanding of possible risks and improvement areas, which will be combined together in the end to provide a joint perspective. This joint view will be the deliverable to fulfil the purpose two.

3.2 Data collection methods

The source of data is one possible criterion how to categorise data. Sometimes, the required information for conducting a research could be already available, however, in many cases researchers need to gather the necessary data themselves to undertake the research study. On this basis, the data can be divided into two parts – primary and secondary (Kumar 2011). Primary data is the data collected from primary sources and according to Krishnaswamy and Satyaprasad (2010) these are the original sources, where the researcher directly collects data that have not been previously collected. Secondary data, on the other hand, is collected from secondary sources, which contain data that have been gathered and compiled for another objective (Krishnaswamy and Satyaprasad, 2010).

There are different concerns that need to be taken into account when choosing the data sources. Krishnaswamy and Satyaprasad (2010) point out some disadvantages of secondary data such as the data might be obsolete or out of date, the available data might not be as accurate as desired or the data might not meet the specific needs of researchers, since units of measure might not match, the definitions used by data collectors and researchers might differ, or the data collection time periods might not be align with the researchers needs. These limitations should be kept in mind, when assessing the secondary data. When collecting primary data, then the researchers can acquire the data in such form that meets precisely their research needs (Krishnaswamy & Satyaprasad, 2010), therefore previously presented disadvantages of secondary data could be avoided. But on the other hand, Kumar (2011) argue that when collecting primary data there are several risks that could reduce the quality and reliability of the data, when they are not taken care of in the proper manner. The risk of letting bias in the data is extra high for beginner researchers (Kumar 2011), so researchers should put extra caution and effort into ensuring the reliability and correctness of data gathering and treatment processes. How the quality of data is ensured in this study is addressed more thoroughly in chapter 3.4.

Both data sources are used in this thesis. To collect the secondary data, a literature review as well as company internal document review has been conducted. Primary data is collected through semi-structured and unstructured interviews. The data collection methods that are used in this study are illustrated in figure 6. More detailed discussion about the methods will follow.

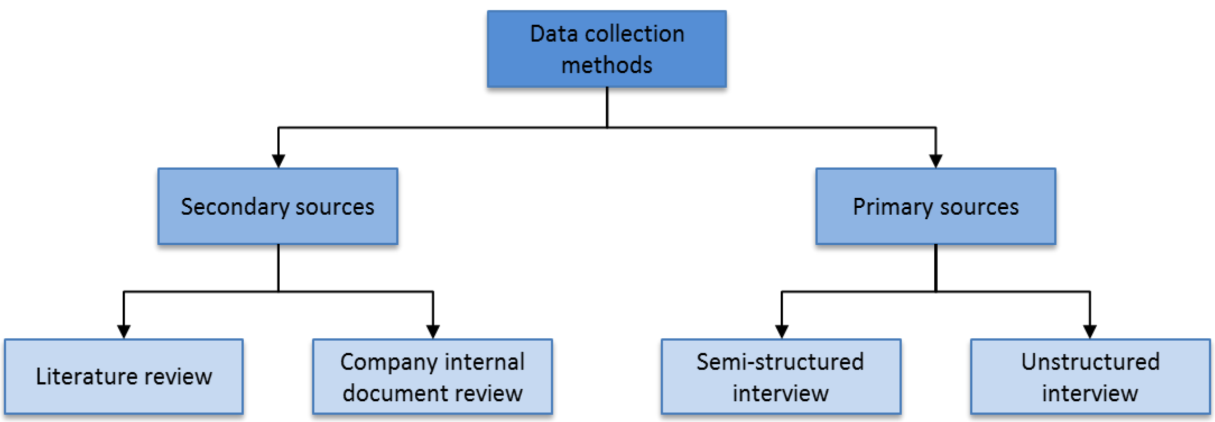

Figure 6 – Data collection methods

3.2.1 Frame of reference

Kumar (2011) argues that literature review is an essential preliminary task and an inseparable part of a research study that creates value to almost every research process step. He defines literature review as the process of going through the existing literature and materials that are relevant to the research area in order to get an understanding about available knowledge and findings in the area of interest. The literature review has the functions of providing a theoretical background to the study, identifying the links between the research object and the current body of knowledge and helping to integrate the findings into the current theories (Kumar, 2011). More specifically, the literature review of this study is used to get both – general and more specific understanding of the area of interest.

First of all, literature review is conducted to help the researchers to find ideas how to target the purposes, which were introduced in chapter 2. Also, literature review helps the researchers to find and evaluate relevant research methods and give guidance how they should be carried out. Secondly, literature review is used to find more specific ideas and means of lead-time reduction in research & development environment from the organizational perspective. These findings will be presented and discussed in chapter 6.

The main data gathering for literature review is done by using Chalmers Library search tool Summon, and Google Scholar. These search engines are used to find academic papers and theoretical literature. Relevant literature suggestions are also received from supervisor and other university experts.

3.2.2 Company internal document review

Additionally to academic literature, several company internal documents and information systems are also used as bases for data. Since these documents and data have been created and gathered by other authors for different reasons, then they are considered as secondary sources. Volvo Cars internal materials are essential to create the understanding of the current set-up and situation of the processes. Among other, these materials help the researchers to prepare for interviews, create interview questions, put the information gathered to context, and map down the processes.

Examples of these materials are process maps, process descriptions, document templates, documents, planning templates, study materials, and internal presentations. The main tool what is used to find materials is Volvo Cars Business Management System (BMS), which encompasses all the business process related materials. Also, Volvo Cars Intranet search engine has been helpful in finding relevant data. Considerable amount of documents have been sent to authors by Volvo Cars employees who the researchers have interacted with.

3.2.3 Interview

According to Burns (1997: 329), an interview is defined as “a verbal interchange, often face to face, though the telephone may be used, in which an interviewer tries to elicit information, beliefs or opinions from another person”. Krishnaswamy and Satyaprasad (2010) point out that additionally to verbal conversation; information can be gathered from gestures, facial expressions, pauses and overall environment. Therefore, interview is a very good method if the goal is to understand the underlying thoughts and problems of the respondent. Kumar (2011) classifies interviews into different categories according to the flexibility level. From one side, structured interviews are very rigid and the questions and the asking process are predetermined regardless to the responses. On the other hand, unstructured interviews have high degree of flexibility in terms of interview structure, content and questions (Kumar, 2011). This way the interview could flow to unexpected areas and unknown data might be revealed. On the other hand, it will be very hard to compare the data gathered from different interviews and time might be wasted in unproductive conversations (Krishnaswamy & Satyaprasad 2010). Different interviewing types can be seen in figure 7.

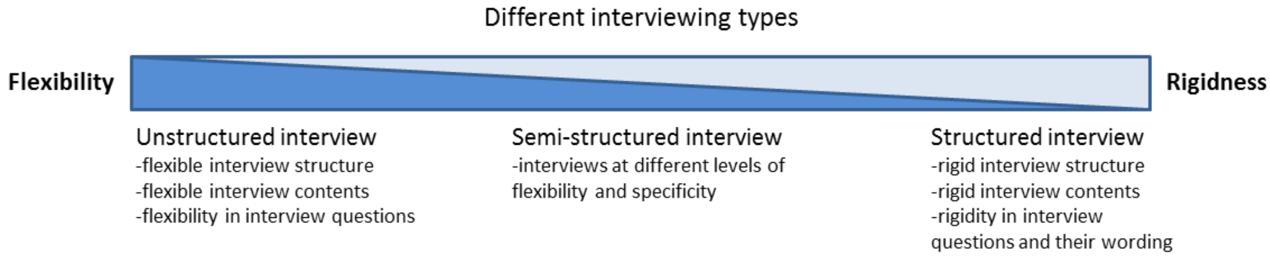

Figure 7 - Different interviewing methods (authors' interpretation of Kumar 2011)

Interviews were conducted with different actors in the test object process and the main aim of the interviews was to get a deeper understanding of the current processes, existing problems perceived by the actors, as well as areas and ideas of improvements. Targeted actors were all related either directly or indirectly to the test object process and jointly they would cover the full process from the planning faces until test object build. This meant that an unbiased and complete "as is" picture, could be constructed. Most commonly, the interviews were scheduled and organized beforehand; therefore there were time to prepare questions and goals for the interview, to get as much useful data out as possible. But since the researchers werr located throughout the research process in Volvo Cars facilities, next to different actors involved in test object process, then there were several opportunities for the researchers to conduct less prepared, spontaneous, and quick interviews on spot. This gave good chances to get clarification of data or extra input from the actors in a fast way. Taking into account the limitations discussed above and the research environment, the researchers were mainly using semi-structured interviews accompanied with several unstructured interviews.

Concerning the semi-structured interviews held with Volvo Car Group employees, questions of interest were prepared and the purpose were communicated to the interviewee beforehand. Also, the goals of the interview, as well as of the overall thesis, were well communicated to the interviewee, in the beginning of interviews, to help the interviewees in providing more relevant and correct information. Since, often the researchers did not have a full understanding of the knowledge base of the interviewee and the existing process under investigation, then semi-structured interviews gave the flexibility to take in relevant side themes, which emerged during interview, but was not seen as a discussion theme beforehand. On the other hand, if a prepared question might turn out to be irrelevant, then the researchers had the option to skip it. Semi-structured interview gave enough flexibility to the conversation, to identify unexpected data while at the same time provides a frame to be efficient and focused.

As mentioned above, unstructured interviews are more spontaneous and took place numerous times during thesis project. This situation could occur for example next to lunch or during coffee break. The purpose was to get fast information input to enhance the research process. For instance, these could have been some follow-up questions to clarify the data gathered through semi-structure interview or asking for explanation of a process step found in Business Management System. It must be mentioned that some meetings with company supervisor could also be categorized as unstructured interviews. An example of that situation would be a regular follow-up meeting without a predetermined goal.

A list of semi-structured interviews conducted during the time period between 19th of February to 29th of April is presented in table 3 below. 21 different semi-structured interviews can be found in the list, but it must be mentioned that regular (at least once per week) meetings with company supervisor have not been added to the list. The reason is that interviews with company supervisor did not follow the same preparation, conducting and follow-up structure as the ones mentioned in the list. They were much looser and flexible in their nature, but they must be mentioned, since the researchers got a lot of valuable guidance and supporting information to conduct the research. Also unstructured interviews were not logged and therefore they do not exist in the table. The column Interviewee(s) represent the initials of the employees interviewed. As it can be seen, in some cases more than one employee was involved in one interview and some employees were interviewed more than once.

Table 3 - List of semi-structure interviews

Date	Interviewee(s)	Interview topic
19.02.2014	TO, BIF, LLBA	Part project leading
21.02.2014	CB	Planning & specification
27.02.2014	AS	Supply chain controlling in Shanghai
28.02.2014	ALA, LS	Material procurement & logistics
03.03.2014	AV	Boxcar management in Shanghai
04.03.2014	BW	Pilot plant & logistics in China
04.03.2014	AL	Project buying
06.03.2014	MV	Purchasing project leading
12.03.2014	AO	Program purchasing
19.03.2014	MJ, MW	Coordination of research project
21.03.2014	MM	Pre-Buy-Off (PBO) and Machine Try-Out (MTO)
26.03.2014	BÖ	Machine Try-Out (MTO) build processes
28.03.2014	TO	Part project plan (DP plan)
01.04.2014	BIF	Activities from release of Bill-of-material (BOM) to material requirement date (MRD)
07.04.2014	CB	Planning
11.04.2014	TO, BIF, LLBA, MW	Coordination & clarification of research project
15.04.2014	MM	Pre-Buy-Off (PBO) and Machine Try-Out (MTO)
16.04.2014	LM	Finances & transfer pricing
24.04.2014	TO	Pre-Buy-Off (PBO) and Machine Try-Out (MTO) series "extra need" material process
29.04.2014	HM	Operations in Maastricht
29.04.2014	PC	Material procurement & logistics in Chengdu factory

The researchers got help from company supervisor in the sample selection of interviewees. Also, a so-called snowball sampling was done, which means that the researchers asked the interviewees to propose actors who they thought it was relevant to talk to. This way it was possible to find new interviewees and go deeper into the research object.

When it was possible, then interviews were conducted face-to-face. Since several interviewees were located in other countries than Sweden, then the researchers had to use either telephone or Microsoft Lync, in order to conduct the interviews. Microsoft Lync program provided also the possibility to share the screens between researchers and interviewees, which made the understanding of each side much better. During the semi-structured interviews all three researchers were present. One researcher was responsible for leading the interview and asking the planned questions, the second researcher was supporting with clarification questions and tracking if the interview goals were met, and the third researcher was responsible for typing the information in to computer and organizing the gathered data after the interview. Regardless of the set responsibility areas of researchers, flexibility existed, so everybody could ask questions if they felt the need for it. In average, the duration of interview was 1 hour. The shortest interviews lasted 30 minutes and the longest ones over two hours. If needed, then follow-up and clarification questions were sent either via e-mail or asked face-to-face during an unstructured interview format.

3.3 Data treatment methods

Next to data gathering, it is also important to discuss how the data is treated. The format of the data could be very different and so could be the data treatment methods. Since one of the goals of the thesis is to analyse the current processes, then process mapping is a possible way how to structure the gathered data in an organized and logical manner, which will make it possible to describe and understand the current situation. When the current state is understood, then risks and improvement areas can be identified. For this reason, process mapping was chosen as a method for data treatment. More specific, Event-driven Process Chain modelling (EPC modelling) and Gantt chart planning were used for data treatment. Theoretical background and description of the concepts are described in the following chapter.

3.3.1 Process Mapping

There are many ways how to map processes and *Event-driven Process Chain modelling (EPC modelling)* is one of them. Davis (2001) defines EPC as a "dynamic model that brings together the static resources of the business (systems, organisations, data, etc.) and organises them to deliver a sequence of tasks or activities ("the process") that adds business value." In other words, EPC defines the business process by linking together four types of objects; events, functions (also called activities), rules and resources (e.g. data, organisation, systems, documents, etc.). Davis (2001) discusses about several things to consider when mapping processes with EPC modelling. For example when looking into functions, the researchers should identify triggers and outcomes, key decision points, branches and links to other processes, data inputs and outputs of each functions, and systems and organizations that support each function. All of these considerations have been in the mind of researchers while conducting the data collection and linking the data into process map. The EPC modelling has provided the researchers a good foundation for organizing the data, though it must be mentioned that since not all the processes were looked from the lowest level (i.e. some functions were still aggregated and not broken down), then in these situations looser modelling approach was used, where not all the specific links were identified. Though, this did not jeopardise the purpose of identifying the risks and improvement areas for reduced lead-time.

Gantt chart was developed already in the beginning of 20^{th} century (Wilson, 2003), but it is still one of the most used planning and controlling tools in project management nowadays (Besner & Hobbs, 2008). Geraldi and Lechter (2012) identified several implications of Gantt chart in managing projects, including time-focus principle. It is argued that Gantt chart gives the user the opportunity to organise activities in time and make time and timings of tasks visible. Therefore, when facing complex projects, it is possible to link different activities together depending on the interfaces and sequences of activities. This will help in building a logical and realistic plan for the whole project; hence identify the lead-time, critical path and critical activities. Gantt chart is used in this thesis to define and analyse the Verification Prototype (VP) build logic in China (presented in chapter 4). The use of Gantt chart was also influenced by the fact that Volvo Cars is currently using Gantt charts to define the projects and therefore using the same method makes the analysis more accurate and simpler.

3.4 Quality of Data

In this section, the quality of the data is discussed; hence, the accuracy of the thesis in terms of reliability and validity is targeted. Sachdeva (2009) discusses that when conducting a research, researcher has to continuously commute between two perspectives – theoretical and observational. In other words, between what is thought about the world and what is actually going on in it. To ensure that those two perspectives match each other, the researchers have to ensure the reliability and validity (Sachdeva 2009). Patel and Davidson (2003) share the similar viewpoint by stating that reliability and validity are two key areas to focus during research process to ensure the quality of research. In this case, the reliability and validity depend on the data generated through the empirical findings and on the data treatment ways. Before reliability and validity are discussed, authors own opinion about the weaknesses of the project will be argued.

First of all, the authors admit, that it was very tough to understand the whole test object process and creating this understanding took up major part of the project duration. Moreover, it was difficult for the authors and for the interviewed actors to translate the information from the overall test object process to the determined scope. The scope was much needed in order to create the boundaries for the project, but since the activities in total process are highly entwined, then it was hard to pick out and connect the right information. Because of the problems discussed, the authors feel that enough depth was not achieved in both the process and organizational view. Some activities stayed still in an aggregated level. This means that there could be improvements to be done in order to get the process even clearer and find new risks and improvement areas.

3.4.1 Reliability

According to Kumar (2011) reliability refers to the consistency in the research findings when the same approach is used repetitively. Related to this thesis, this means how well the outcome of the interviews could be recreated. Sachdeva (2009) points out that when discussing reliability, then it is also important to assume that what is measured is not changing. It is not possible to get the same outcome in different time points when the research object is in constant change, even if exact replicas of methods are used. This is very much the situation for the current thesis; since, the test object process is in constant change and development, then the interview outcomes might not be the same even in near future. Therefore, reliability has to be discussed in a hypothetical situation, where the repetitive researches could be done in the exact same point of time. If the authors can ensure reliability in this hypothetical situation, then this would be sufficient to call the thesis reliable.

Patel and Davidson (2003) state that standardized interviews are a mean to reach good reliability. It is difficult to standardize semi-structured and unstructured interviews, which are used in this thesis. Kumar (2011) supports that idea, stating that when the research advocates flexibility and freedom, then it is difficult to reach high level of reliability. Nevertheless, the researchers have tried to standardise the interview process. Firstly the goals and purposes of the interview are set followed by the compilation of interview questions. During the interview the purpose of the interview and thesis are introducing clearly to the interviewee. A standardisation of roles and responsibilities between researchers existed as well as standardised recap and follow-up process. This process standardisation was implemented in the semi-structured interviews.

Additionally, according to Patel and Davidson (2003) recording the interview can help the interviewers to guarantee that the answers given by the interviewee is fully understood. The interviews were not audio recorded, but they were all logged by one researcher. Also, since three different researchers were present at each interview and a recap process of discussing the results of the interview was conducted, then the combination of three researcher's interpretation of the data ensured that the interviewee was fully understood. Additionally, follow-up with interviewee was done if there was a risk of misinterpretation. The semi-structured and unstructured interviews gave the opportunity for interviewers to ask questions openly and explain the meanings when ambiguity or misunderstanding emerged.

3.4.2 Validity

According to Kumar (2011) validity refers to the ability of the research instrument to demonstrate that it finds out what it is designed to find. In other words, does the study observe or measure what it is intended to do. Jacobsen (2002) divide the validity into two parts – internal and external. The internal validity concerns that it is measured, what is actually set to be measured, while external validity concerns that the finding actually can be generalized to other context.

One way how researchers have ensured the internal validity, as mentioned earlier, is that in the beginning of every interview the purpose and the scope of the thesis, as well as the goal of the interview, was communicated to the interviewee and it was made sure that interviewee understood that. This approach helped the interviewee to understand what is relevant for the researchers to know in order to fulfil the thesis purposes, as well as cut out potential ambiguity. Moreover, the interview outcomes were discussed afterwards with company supervisor to identify if there might have been any misunderstandings or mismatch in the data. Since the company supervisor has expertise overview of the research object, then this kind of validation of data helped to increase the internal validity. Lastly, triangulation was used to increase the internal validity. Triangulation basically means that more than one method or data has been used to study a phenomenon (Bryman & Bell, 2007). An example would be the study of process descriptions and maps in the Business Management System (BMS) next to interviews with several actors about the same processes. By continuously comparing the process maps and interview responses, then it was possible to pinpoint out mismatches. In some cases the mismatches were caused by misinterpretation of interviewee or the process description, but in other the process map could have been outdated or not representing the actual activities. Continuous comparison of different data about same phenomena has increased the internal validity.

As mentioned, then external validity is about whether the results can be generalized to other context. This research can be considered mainly as qualitative. According to Bryman and Bell (2007) qualitative research is digging more into depth than breadth, thus the focus is strongly towards the context. Therefore, this makes it harder to transfer the findings to other environments. For instance, the test object process varies between different car manufacturers; hence, it can be questioned if the findings could be used in other companies. Nevertheless, some findings could be still applicable for other manufacturing companies with complex products that meet the problems of globalized test object process. Kumar (2011) states that even though it is hard to establish transferability in a qualitative research, extensive and thorough description of the research process can increase the degree of transferability. This makes it easier for others to follow, replicate and adapt the results to their context. Consequently, the researchers have tried to extensively describe the research process.

Concerning the validity of the research approach, then the authors admit that there, of course, exist other possible methods and ways how to approach the raised purposes of the thesis. The used research approach is one possible way how to find answers to the questions and it can be argued that different approaches would result in slightly different results. For example, using a different concept, instead of complexity, to structure the organizational view of the research object can reveal different facets of risks and improvement areas. Nevertheless, the authors believe that the used approaches can be considered as one appropriate way to conduct the research.

4 VERIFICATION PROTOTYPE BUILD LOGIC IN CHINA

The total chapter aims at fulfilling purpose 1. Firstly, a general description of what the Verification Prototype (VP) build logic means, and how it relates to the test object process will be described. Secondly, the chapter focuses on the context of China, how the build logic works there. Finally, analysis of the build logic in China will be conducted and improvement suggestion will be presented.

4.1 Planning

Firstly, the Verification Prototype build logic is a build strategy that is created for each new project; it is created in the planning phase, in the form of a plan labelled *Integrated Activity plan* (IA-plan) at Volvo. Thus, a brief and simplified introduction to the planning phase will be explained

When Volvo wants to build a test object, a new project is created. The projects differ in timespan and extent depending on the purpose of the project. E.g. when a total new model shall be released a lot of different test series will be built during the course of the project but if it is only minor changes to an existing model the need for different test series are consequently less. Volvo has many of these projects ongoing simultaneously, and thus there is a need for a planning function in order to make sure that the different projects do not disrupt each other. Meaning that, resources and facilities to build test series are limited, hence putting constraints on when projects can start, and test series within the project can be built. The planning function is also responsible for the total time plan of each project, breaking it down to detailed plans with critical activities and delivery times.

Given this background, the planning is the first activity that needs to start in the Test Object Process. When the planning function gets a need for a new project they first look at the preliminary Vehicle Program Plan (VPP), which is the main time plan that contains long term planning of upcoming projects and series. The planning function steer in new projects with accordance to the Vehicle Program Plan (VPP), looking into factors such as; time and resource conflicts, holidays, target factory, and extent of project. Taking these factors into consideration, together with the Integrated Activity plan (IA-plan) template, the planning function adjust the Integrated Activity-plan template to fit the concerned project and creates a more specific Integrated Activity plan (IA-plan) for each test series within the project. The reason why a specific Integrated Activity plan needs to be created is because, the template shows average times and activities, that needs to take place during the Verification Prototype (VP) build, but as mentioned, all project differ in extent and timespan. That forces the planning function to adjust the template with correct times and activities to fit the concerned project. Additionally, a more detailed plan on important delivery times and areas during the whole project is created and is called “Del-Projekt plan” (DP-plans) or part project plan in English. Further, the planning function break down the part project plan (DP-plan) one more step, to an even more detailed plan called Activity plan. Lastly a table runner is created, which contains the number of build starts in each factory per week.

The part project plans (DP-plans) and Activity plans are the tools that are used today by the Test Object Managers (TOMs), who will run the project when the planning is done and the project starts. The other plans are updated and put into different Volvo database systems. For a simplified illustration of the planning process see figure 8 below:

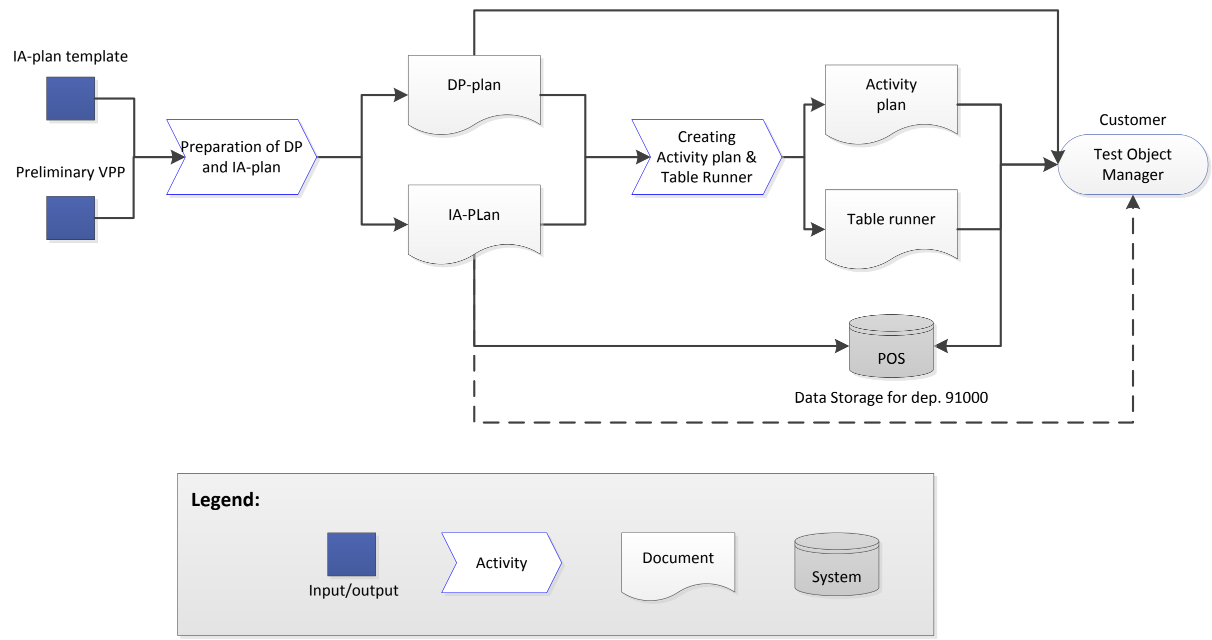

Figure 8 - Simplified process map of the planning phase within the Test Object Process

A summary of each described plan is shown in table 4 below:

Table 4 - Summary of plans used and created by the planning team when a new project shall be planned prior to project start

Plan name	Explanation	Created by	Used by
Vehicle Program Plan (VPP)	Main time plan containing all M1 and VP series with Material Requirement Dates and the time when software should be available (CRB times)	Management	Planning function
Integrated Activity Plan (IA-plan), template	Build logic for software, physical build and engines. A general template to be updated with accordance to the concerned project	Management	Planning function
Integrated Activity Plan (IA-plan), specific	Build logic for software, physical build and engines for the specific project	Planning function	Test Object Manager
DP-plan	Delivery times of important areas during the series, specific to each project	Planning function	Test Object Manager
Activity Plan	Input from DP-plan and broken down into a more detailed level, specific for each project	Planning function	Test Object Manager
Table Runner	The number of build starts per week in the target factory	Planning function	Target factory

More specifically, what is an Integrated Activity plan (IA-plan)? At the point in time when all material needs for a certain test series are secured, the actual build of the test cars can start. In order to get the timings and dependencies correct in the build, and thus deliver the test car on the right time, the Integrated Activity plan (IA-plan) shows the build logic. In Volvo there are three main activities that happens' in parallel during the build, namely; the physical build of the test car, the main assembly of the engine for the test car, and the testing of needed software in the test car. An Integrated Activity plan (IA-plan) is basically a Gantt-chart that shows dependencies between the different tasks or activities in the plan; a general example is shown in figure 9 below. All tasks are connected with each other through preceding relationships which are illustrated as arrows. This kind of layout gives the opportunity to analyse the logical fit of the tasks as well as critical paths in the plan.

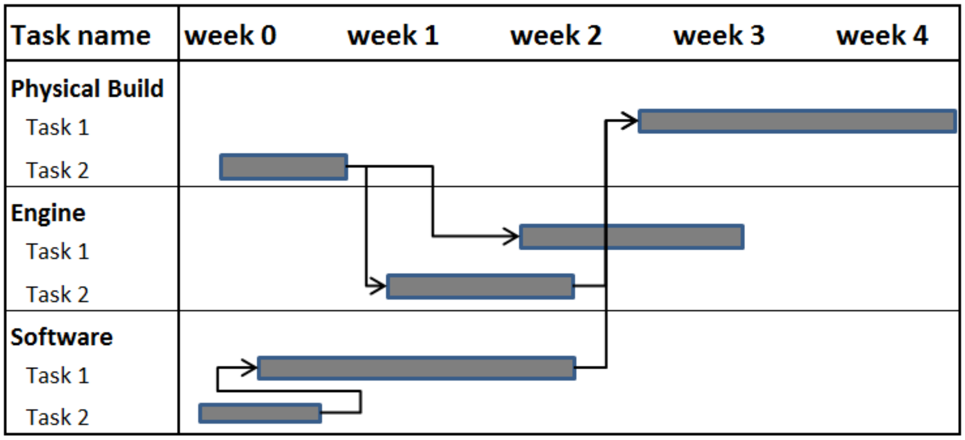

Figure 9 - A general model of an Integrated Activity plan which shows at what time a given task should be carried out and how they depend on each other.

To summarize, the build logic for a Verification Prototype (VP) series is created in the planning phase and are showed in the Integrated Activity plan (IA-plan). Naturally, since the Integrated Activity plan (IA-plan) contains the build logic, the actual activities of the plan occurs in the build phase of the Test Object Process, as is graphically illustrated in figure 10 below.

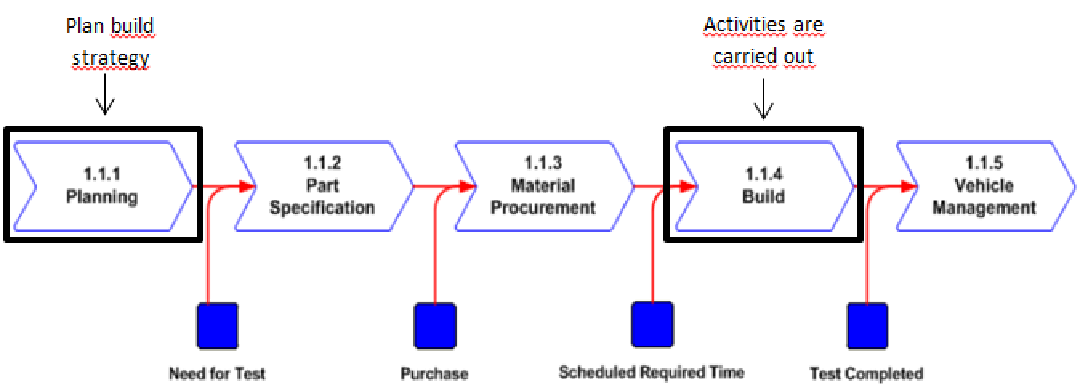

Figure 10 - The main flow of the entire Test Object Process, highlighting where the IA-plan is used.

4.2 Integrated Activity plan for China

In order to analyse the current Verification Prototype (VP) build logic for China, a realistic current situation has to be understood. Since presently there is not any thoroughly developed Integrated Activity plan (IA-plan) template for China, a new template has to be mapped down. In this sub-chapter, the Integrated Activity plan (IA-plan template) for China, which is compiled by the thesis authors, is presented and discussed. Using the information gathered through interviews with people who are closely working with the activities within the Verification Prototype (VP) build logic, the authors were able to construct the current Verification Prototype (VP) build logic in the Volvo form of an Integrated Activity plan (IA-plan) template for China, see Appendix 1. The next coming sections will explain how the Verification Prototype (VP) build logic works, how the Integrated Activity plan (IA-plan) is built up, and discussions regarding implication of the constructed build logic for China. First a brief explanation about what plants are involved will be given. Taking the general model presented figure 9 above and assign specific locations where the activities are carried out.

There are three locations showing in the Integrated Activity plan (IA-Plan) template for China, where the activities are carried out; Chengdu production plant (VCCD), Zhangjiakou engine plant (ZJK) and Shanghai pilot plant (PD2). These three locations correspond respectively to physical build, engine, and software in the general model in figure 9. It is important to point out that geographically these facilities are located far away from each other. The distance from Chengdu to Zhangjiakou is 1800 km, from Zhangjiakou to Shanghai is 1400km, and Shanghai to Chengdu is 2000 km, see figure 11 below. Compared with Europe, where the longest transportation distance between facilities is 180km. These three locations with their roles are briefly described below.

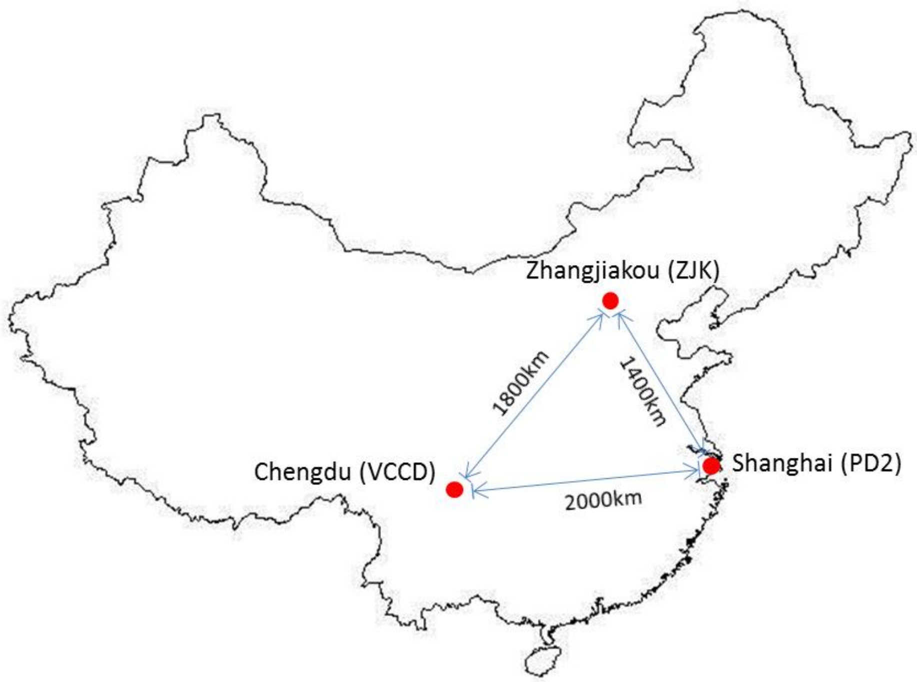

Figure 11 – The concerned China plants in the IA-plan, showing location and distances between the plants

The Chengdu production plant (VCCD) is the newest Volvo car plant. It is a modern production plant that has the full capability of building complete cars also including module builds. The Volvo Cars Manufacturing System is adapted in Chengdu (VCCD), therefore, similar standards and processes are implemented as in the European plants. Regarding the Integrated Activity plan (IA-Plan), Chengdu (VCCD) is responsible for the complete build, assembly of the test cars and verifications of cars encompassing such process steps like; body shop, paint shop, and final assembly, which corresponds to the acronyms of; A-, B- and C-Shop.

Zhangjiakou engine plant (ZJK) produces engines for Chengdu (VCCD). Zhangjiakou (ZJK) is operated in joint venture in which Volvo Cars holds 30 per cent. The remaining part will be held by other companies within Geely Holding Group. Within Integrated Activity plan (IA-Plan), Zhangjiakou (ZJK) is responsible for the build and testing of engine which is transported to Chengdu (VCCD) for the final assembly of the test car.

In Shanghai, the pilot plant PD2 is located, where test objects are built and tested. In the Integrated Activity plan (IA-Plan) Shanghai (PD2) is responsible for the build of a so called boxcar, which is then used to carry out different needed electronics and software tests. One of the key activities carried out in Shanghai (PD2) concerning the Integrated Activity plan (IA-Plan), is the integration test. The integration test should ensure that different software are capable of working with each other as well as make sure that the series can be built together in a good way from the electric part side. Next, the created Integrated Activity plan (IA-plan) template for China, and critical paths in the plan will be described and discussed.

4.2.1 Critical path activities

In the Integrated Activity plan (IA-plan) there are two type of tasks; milestones and activities. Milestones are illustrated as rhombuses and they state a specific time when an event has to happen. An example of a milestone is Material Requirement Date (MRD), which states the time when materials are needed, in order to carry out activities in the plan. Activities are illustrated as bars. The length of the bar will indicate the duration of the activity. It must be mentioned that the presented durations of the activities are averages and they might differ between different projects.This means that in the planning phase, when creating the specific Integrated Activity plan (IA-plan) for each project, the durations have to be revised to fit the project characteristics. All activities and milestones are connected with each other through preceding relationships, which are illustrated as arrows. More detailed descriptions and goals, of activities and milestones, can be seen in Appendix 2. As mentioned above, the activities in the Integrated Activity plan (IA-plan) are done in parallel between three facilities. There are both critical path of activities for each facility and there is one aggregated critical path for the whole plan. Next, these critical paths are described.

Activities and milestones, within the Integrated Activity plan (IA-plan) for the production plant in Chengdu (VCCD) are presented in figure 12. The activities start after the milestone Material Requirement Date 0 (MRD0), which is the time when all the materials for body build are needed. The first activity in the critical path is material handling, followed by body build, which is called A-shop. After the body is assembled, it goes to B-shop where the painting of the body is done. The last step is the physical build and verification of the test car, which is called C-shop. Before the C-shop can begin several activities have to be finished such as material handling for final assembly, external and internal modules handling and software testing. The duration of critical path activities in Chengdu production plant (VCCD) add up to 40 working days.

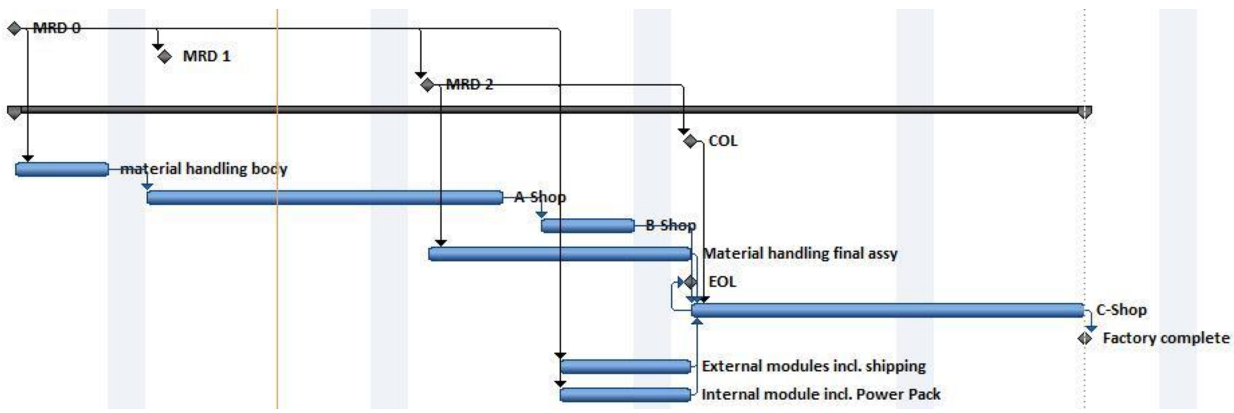

Figure 12 - IA-plan activities and milestones carried out in VCCD in connection with physical build of the test car

Activities and milestones, within the Integrated Activity plan (IA-plan) for the engine plant in Zhangjiakou (ZJK) are presented in figure 13. Note that electrical metal boards, which are needed in engine testing, are assembled in Shanghai pilot plant (PD2) and shipped to Zhangjiakou (ZJK). Five days of transportation time between facilities are caused by the long distances presented in figure 11 above. Since the compilation of material kit for electrical metal board, assembling it and shipping it from Shanghai (PD2) to Zhangjiakou (ZJK) takes longer time then the engine assembly itself, then the critical path follows these firstly mentioned activities. Similarly to Chengdu (VCCD), the activities are initiated by milestone MRD0. After the electrical metal board has reached Zhangjiakou (ZJK) and the engine is assembled, testing of the engine will take place. After the testing is completed the engine is shipped from Zhangjiakou (ZJK) to Chengdu (VCCD) for the final assembly. The critical activities mentioned above relating to engine build stand for 21 working days.

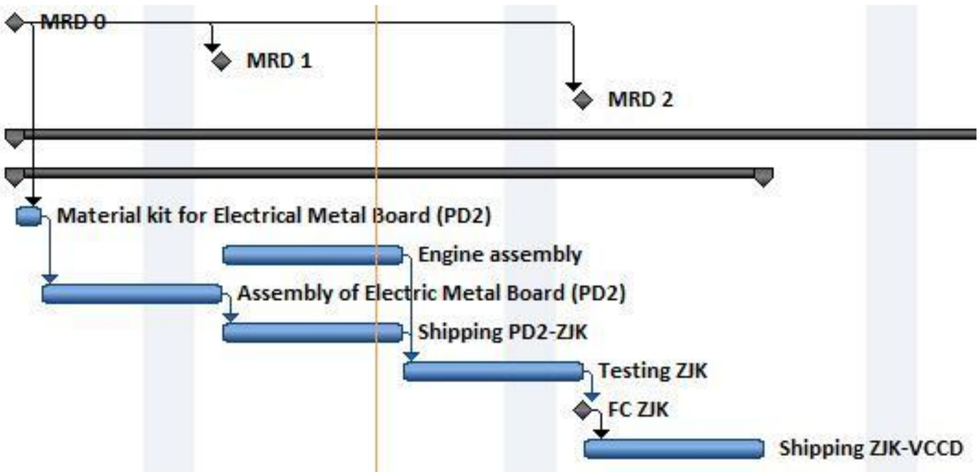

Figure 13 – IA-plan activities and milestones carried out in ZJK and PD2 in connection with engine build

Activities and milestones, within the Integrated Activity plan (IA-plan) for the pilot plant in Shanghai (PD2) are presented in figure 14. After MRD0 material handling for boxcar build will follow. Next activity in critical path is the boxcar build, which is followed by integration test. If the integration tests are done, then the software will be released to factory systems, but before the software can be downloaded to cars, factory data preparation has to be conducted. Next to the described critical path there are several other tests and activities connected to software testing, but these activities do not add time to the critical path, since they can be done in parallel. The described critical activities add up to 23 working days.

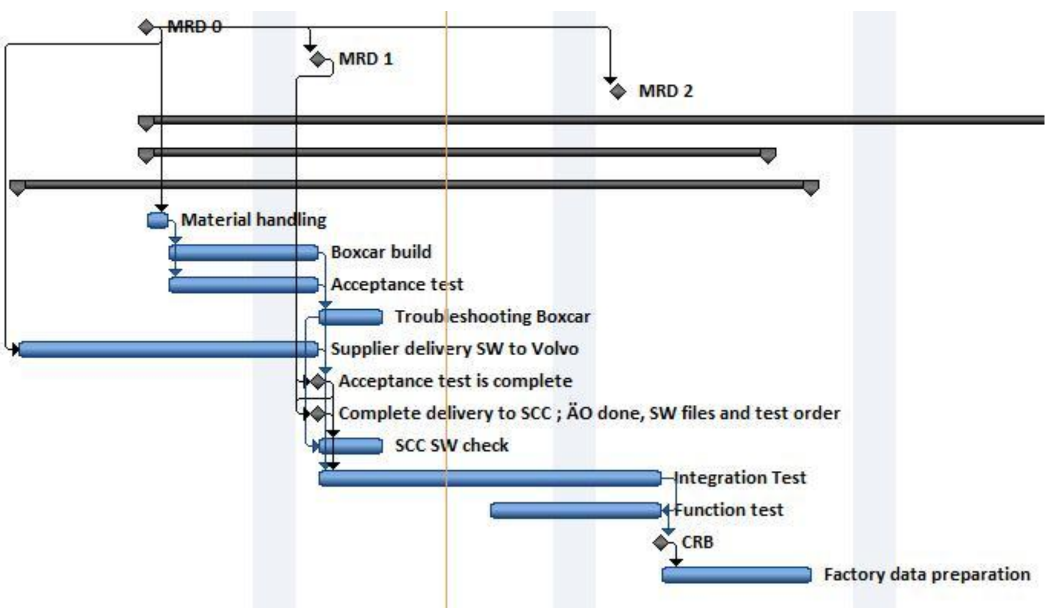

Figure 14 - IA-plan activities and milestones carried out in PD2 in connection with software testing

When looking at the three critical paths described above, then it could be assumed that the aggregated duration of the critical activities is equal to the longest critical path length – 40 working days. But when combining all activities together, it can be seen that aggregated critical path duration is actually 41 working days. This is caused by the fact that the start of C-shop in Chengdu (VCCD) has to wait for one day because the engine assembly, testing and transportation takes more time then C-shop pre-activities done in Chengdu (VCCD).

Now when the Verification Prototype build logic is drawn up in an Integrated Activity plan (IA-plan) template for China, see Appendix 1, it is possible to deduce the material requirement dates for body build, engine build, boxcar build, software testing and final assembly. For example, Material Requirement Date 0 (MRD0) is 41 days before the first car has to be verified, MRD1 (time when software has to be delivered) is 6 days after MRD0 and MRD2 (time when material for final assembly has to be delivered) is 16 days after MRD0. These milestones are crucial to take into account when planning pre-activities that are eventually resulting in material deliveries.

4.3 Improvements to increase delivery precision

The Integrated Activity plan (IA-plan) gives input to; how long different activities will last, and how long-lasting is the critical path. From there the Material Requirement Dates (MRDs) can be derived that have to be taken into account when conducting other plans. As explained above, Integrated Activity plan (IA-plan) template is input to part project plan (DP-plan), which is a plan that covers important delivery times in a project. Part project plan (DP-plan) covers activities from; the defining of the series demands, until the delivery of first test car. Therefore, Integrated Activity plan (IA-plan) activities are the last steps in part project plan (DP-plan). Part project plan (DP-plan) is the main plan, which Test Object Managers (TOMs) use to track the deliverables and deadlines in a project. Therefore it is important to have correct times in that plan. For this reason the authors looked into different part project plans (DP-plans) to evaluate if the activity durations match to the created Integrated Activity plan (IA-plan) template.

Three different part project plans (DP-plans) for China test series build have been taken under observation. Those three plans have been all executed in the past. These three plans represent the full sample of previous part project plans (DP-plans), which targeted the Verification Prototype (VP) build in Chengdu production plant (VCCD). The average activity times from three plans have been calculated and showed in figure 15. These durations are compared to the activities in Integrated Activity plan (IA-plan) template for China. Also the durations of activities in Integrated Activity plans (IA-plan) for Europe have been presented to illustrate the differences in China and Europe. Activities that were possible to draw out from part project plan (DP-plan) are presented, with addition of engine build what was added to express the Europe and China project timing differences.

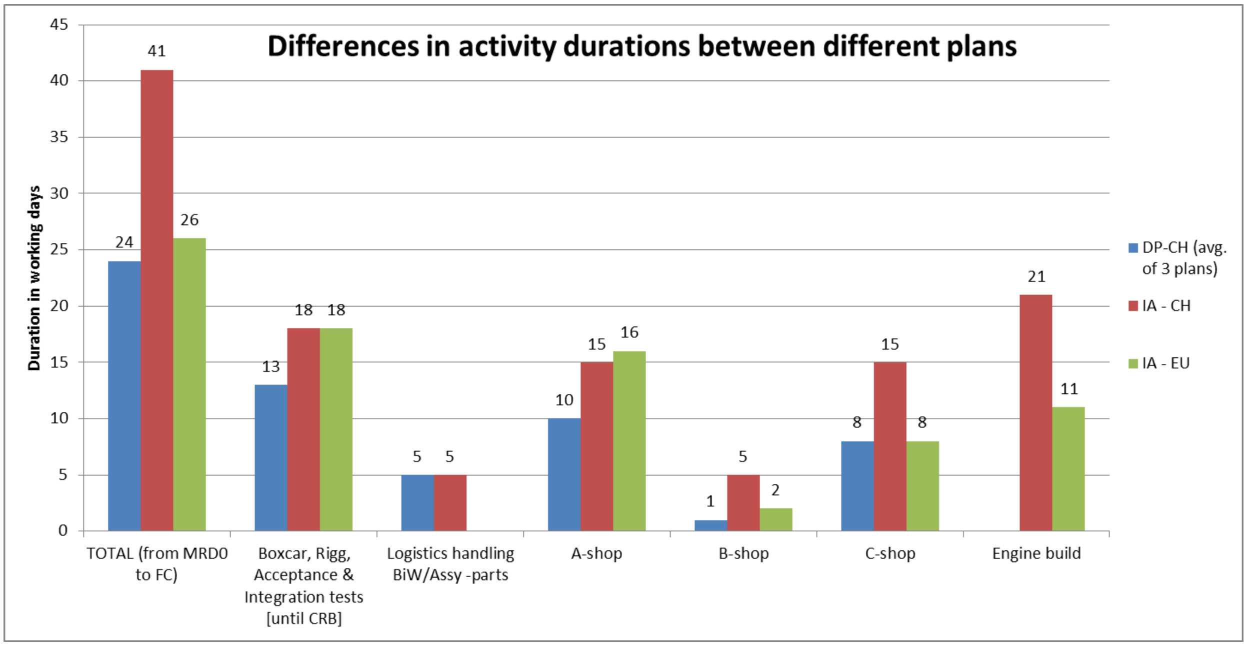

Figure 15 - The differences in activity durations between different plans

Firstly, there are a couple of differences between Integrated Activity plans (IA-plans) in Europe and China. For example the engine build takes almost double amount of working days to be finished. This is due to the fact that engine build encompasses two long distance transportations. First transportation is due to the fact that Zhangjiakou (ZJK) does not have the capability of assembling a component used in the engine, called electrical metal plate. Therefore it has to be shipped from Shanghai pilot plant (PD2). The second transportation comes from the need to ship the assembled engine from Zhangjiakou (ZJK) to Chengdu production plant (VCCD). Similar transportation (from engine plant to build plant) is done in Europe as well, but the difference comes in from distances. Consequently, added transportation times between the plants need to be considered. In this case, five days are added in all transportations between the plants and that is where the ten days difference in lead-time comes from.

Another difference, which is not as obvious, is the fact that the Shanghai pilot plant (PD2), cannot build complete cars. Shanghai (PD2) does not have the capabilities in terms of resources and equipment. Hence, the physical build of the complete test car is done in the production plant, in Chengdu (VCCD), compared with Europe where the Verification Prototype (VP) is built in the pilot plant in Gothenburg (PVÖ). This fact leads to some complication in the Verification Prototype (VP) build logic when comparing with the European build logic. Even though the physical assembly of the test car is faster in a production plant there is a big difference in the total time of the C-shop activities. The verification and testing of a complete test car takes longer time in Chendu production plant (VCCD). Figure 15 shows that the total time for C-shop is 15 days which is seven days longer then in the European build logic.

Secondly, figure 15 conveys clearly that the part project plans (DP-plans) underestimate the duration of activities in the Integrated Activity plan (IA-plan). The total duration of activities from first material requirement date (MRD0) to the factory complete (FC) milestone are 24 working days for part project plan (DP-plan) and 41 for Integrated Activity plan (IA-plan). Difference of 17 working days is substantial. One possible reason for those differences is that part project plans (DP-plans) for China have been developed with the mind-set that activities in China have the same characteristics as in Europe. This mind-set has been proven to be wrong.

Outcome from this situation is that the Material Requirement Dates (MRDs) in part project plan (DP-plan) are set too late and even if the Material Requirement Dates (MRDs) times are met, then it is still impossible to finish the project in time. Therefore the conducted Integrated Activity plan (IA-plan) template should be taken into consideration when creating part project plan (DP-plan) in the planning phase. This sets the base to ensure that Material Requirement Dates (MRDs) are correct, and improvement on the delivery precision can be achieved. From those timings the pre-activities can be scheduled and if those preceding activities are carried out in time then the project has potential to be finished on time. Correctly set delivery times are the foundation for increased delivery precision.

With the conclusion, that the Material Requirement Dates (MRDs) should be set according to the developed Integrated Activity plan (IA-plan) template to improve the delivery precision, the first purpose of the thesis is fulfilled. The correct Material Requirement Dates (MRDs) are prerequisites for moving forward to solve the second purpose of the thesis, which is to identifying risks for increased lead-time and highlight improvement areas for reduced lead-time in the process of getting material from Europe to test series build in China. In other words, the second purpose is dealing with activities that precede the Verification Prototype (VP) build. The following chapter five will examine the second purpose from the process view and thereafter, chapter six will investigate it from organizational view.

5 PROCESS OF GETTING MATERIALS FROM EUROPE TO CHINA

In this chapter, the process view to find risks of increased lead-time and improvement areas for reducing the lead-time is presented. Firstly, a description of Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) series is provided followed by the aggregated activity and lead-time test object process maps. Thereafter, more specific current state process maps are presented. The chapter ends with a discussion about risks of increased lead-time and improvement areas for reducing lead-time.

5.1 Description of Pre-Buy-Off and Machine-Try-Out series

Previously, the Verification Prototype (VP) series has been explained thoroughly, in chapter 4 about the build logic for the Verification Prototype (VP) build. In the introduction, the concepts of Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) were briefly mentioned. This chapter will more thoroughly explain the meaning of what these two concepts are, and where they occur in the process of getting material to China, in order for the reader to better understand: the processes, risks and improvement areas that will be presented in chapter 5.2, 5.3, and 5.4

Firstly, often when Volvo shall introduce new car models, or introduce a model year change, new or adjusted tooling is required in the production plant, in order to produce and assemble the car. This is where Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) come in to the picture. Those two processes are tooling tests with the purposes of verifying that the new tooling can, produce parts according to specification, and that the production line can, produce with accordance to a desired tact time. More specifically, Pre-Buy-Off are tooling tests at the tooling supplier and Machine-Try-Out are tooling tests at the production plant. Here it should be noted that both the process of Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) does not need to occur every time, it depends whether totally new tooling is needed or not, and which tooling supplier that should be used.

5.1.1 Pre-Buy-Off

The Pre-Buy-Off (PBO) process is, as mentioned, tooling tests at the supplier when totally new tooling is needed. Some examples of tooling could be; welding robots, lifting tools, fixtures or, rigs. In order for the supplier to be able to conduct tests on these tooling, they need to have some specification or reference point, in order to verify whether the tooling are producing desired results or not. Hence, the needs of test material arise. Test material could e.g. be; similar tools, raw material, pre-series parts, or production parts. In scope of this thesis are the production parts, and the other test materials will not be discussed further. In Pre-Buy-Off (PBO), production parts are sent to tooling suppliers to verify correct geometry. The correct finish on the surface and tolerances does not need to be 100% correct at this point in time, due to the fact that Pre-Buy-Off (PBO) occurs up to 20 weeks in advance of the actual Verification Prototype (VP) build.

It might sound strange that tooling suppliers should need production parts since; clearly those parts are already being produced by another supplier with functional tools and why would Volvo want more suppliers then necessary. However, one should keep in mind that the tooling suppliers referred to here, are suppliers located in China, which might not have supplied to Volvo China operations before. Further, since the Pre-Buy-Off (PBO) occurs early in the test object process, the authors make the assumption that no local Chinese suppliers for production parts are ready yet. Consequently, production parts have to be shipped from Europe until the local suppliers are ready to supply the parts. In other words, China operations needs help and support from European operations. This assumption, i.e. that local suppliers are not ready, has rather big consequences on the process of getting support material from Europe to China. These consequences will be discussed further below, in chapter 5.2 and 5.3.

5.1.2 Machine-Try-Out

After the Pre-Buy-Off (PBO) tooling tests are done, the tooling are shipped to the production plant for tests in the actual production environment. With big tooling changes, such as a new robot-line, the production line need to be re-built and this will disrupt normal production. At this stage it is still the supplier who is responsible for their tooling, and will be accountable for any need of changes in the tooling. Often, more than one Machine-Try-Out (MTO) is carried out because some iterations are needed in order to get the tooling to produce according to all specification needed. Further, at this stage the tests should verify that the tooling work together in a production process. The goal is to ensure that that production process can run at full speed without e.g. the robots cannot reach a certain weld spot or lifting tools for body parts do not fit in this particular car. As said earlier, a Machine-Try-Out (MTO) can also occur without a Pre-Buy-Off (PBO) process as predecessor. A situation like that could e.g. happen when a car is launched in China but it is already in production in Europe, and a decision has been made that the same tooling supplier that is used in Europe will be used for China as well. Meaning that, needed tools already exist, and that Volvo only needs to test the tools in the production plant in China for process verification. Additionally, the Machine-Try-Out (MTO) should only verify tooling for body parts, complete or part of bodies, and paint shop activities, thus if a lifting tool is needed in the final assembly, this is not a part of the Machine-Try-Out (MTO).

5.1.3 Time frame

Regarding the duration, and when in time the Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) processes occur, in relations to the Verification Prototype (VP) build, varies from project to project. Regarding the Pre-Buy-Off (PBO), it will depend a lot on the tooling supplier’s capacity and, of course, how complicated the tool is. The Machine-Try-Out (MTO) length is usually about 3-5 weeks; however, it will disrupt the current production, which is unacceptable. Therefore, Machine-Try-Outs (MTOs) need to be scheduled at times when the production is not running. This, in turn, means that there are not many times that can be used for Machine-Try-Outs (MTOs). E.g. in Sweden, about 95% of the Machine-Try-Outs are done in the summer vacation. Weekends could also be used for smaller changes in the production line, but since the ordinary production line need to be restored until Monday the testing will be ineffective. Further, this timing issue could also affect the test material need. Even though the scope is only production parts the extra need of test material for Machine-Try-Out tests need to be considered. There are normally not big problems to send production parts from correct European suppliers to China, but if the Machine-Try-Out tests should be conducted in the vacation time, whilst the actual car launch could be the year after, then problems could arise. Purchasing orders are not ready for China, or documentation issues which will cause the parts to get stuck in China customs are some of the problems that could arise if the Machine-Try-Outs are held too long in advance of the actual Verification Prototype build.

In Volvo Car Group there is a function called; *Analysis and verification need* (AVB), who together with the production plant is responsible for the timings and the conduction of the Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) tests. For the reader guidance, the main takeaways from this chapter are summarized in table 5 below:

Table 5 - Main takeaways from Chapter 5.1

Takeaways from chapter 5.1
• Pre-Buy-Off (PBO) tests done at a tooling supplier where materials is needed in order to verify if the tooling works correctly
• Pre-Buy-Off (PBO) materials are assumed not to be ready from the correct production supplier, due to the early occurrence in comparison with the Verification Prototype (VP) build. Leading to the need of support material from incorrect suppliers in Europe.
• Machine-Try-Out (MTO) is a tooling test at the production plant that shall mass-produce the car, where material need is mainly body parts
• Big tooling changes in the Machine-Try-Out (MTO) process will require the production plant to rebuild the production line and this constraint need to be considered when scheduling Machine-Try-Outs (MTOs).

5.2 Aggregated test object process

Before going into the details in the process of getting production materials from Europe to China for Pre-Buy-Off (PBO), Machine-Try-Out (MTO), and Verification Prototype (VP) build the authors shows the processes on a highly aggregated level. Hopefully, it will help the reader to better understand the detailed process maps that follow in the next coming sections (sub-chapter 5.3 and 5.4*)* and relate the details to an overall picture. Additionally, the authors want to explain some of the challenges that this process view presents and that it may not always be as straight forward as it seems.

5.2.1 Activity process map

At this aggregation level the processes looks like figure 16 below. For all three processes; planning is done in collaboration with the production plant and R&D department in Gothenburg, specification is done in Gothenburg. The activity of specifying simply means to enter all needed part numbers into a Volvo test object system called POS. After specification, the purchasing department, in either China or Gothenburg, has to place purchasing orders on the specified parts. Since the scope is about production parts, there already exists purchasing orders for Europe, but new orders need to be created for the target factories in China. Since, as explained in the background, Europe and China operations are basically two different companies, and if Europe operations are sending parts to China operation, they need to sell the parts and make a profit, they cannot give them away. When the purchasing department have done their job and placed orders, the production parts can be called-off from the supplier, and finally transported to China.

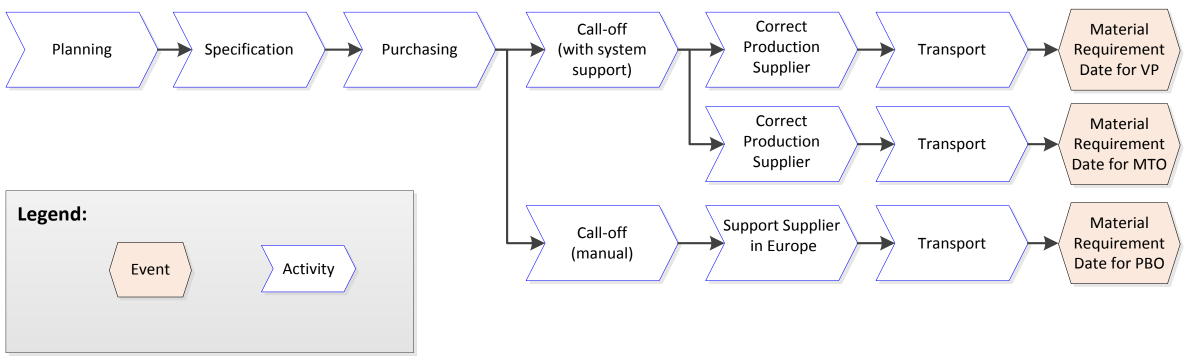

Figure 16 - Aggregated activity process map for Verification Prototype, Machine-Try-Out, and Pre-Buy-Off

For Verification Prototype (VP) parts and Machine-Try-Out (MTO) parts, the call-offs can be done with system support, meaning automatically calling-off to the correct supplier that will supply the parts for the actual production later on. How, why, and the importance of this statement will be further explained in chapter 5.4, where the detailed process map for Verification Prototype (VP) and Machine-Try-Out (MTO) are presented. For Pre-Buy-Off (PBO) material, the situation is not the same, the call-offs need to be sent manually to suppliers that are not the correct production suppliers. The difference lies in the timeframe, when in time the different processes occur. The Pre-Buy-Off (PBO) is carried out significantly earlier, and as this is a product development process, changes and updates will occur, which will simply make the different functions to not be ready with their work in time. E.g. the purchasing department does not have time to work with sourcing and find a good supplier, or an engineer has not finished their work. The implications of this fact will be further explained and analyzed in chapter 5.3, with the detailed process map for the Pre-Buy-Off (PBO) process.

5.2.2 Lead-time perspective on the test object process

As can be seen in the figure 16 above, the process for Verification Prototype (VP) material and Machine-Try-Out (MTO) material are similar and will be presented together in the next coming section, whilst the Pre-Buy-Off (PBO) process will be presented separately. What are not seen in this strict activity view are the lead-times. Looking at the processes from an activity point of view does not show that the lead-time varies both between the processes and within. E.g. when Verification Prototype (VP) material, needs to be sent from Europe, it could contain hundreds of parts and all the activities in figure 16 does not happen simultaneously after each other. Instead the lead-times could be seen as time-windows when the activities need and can happen, in order to reach the Material Requirements Dates (MRDs). This is illustrated in figure 17 below:

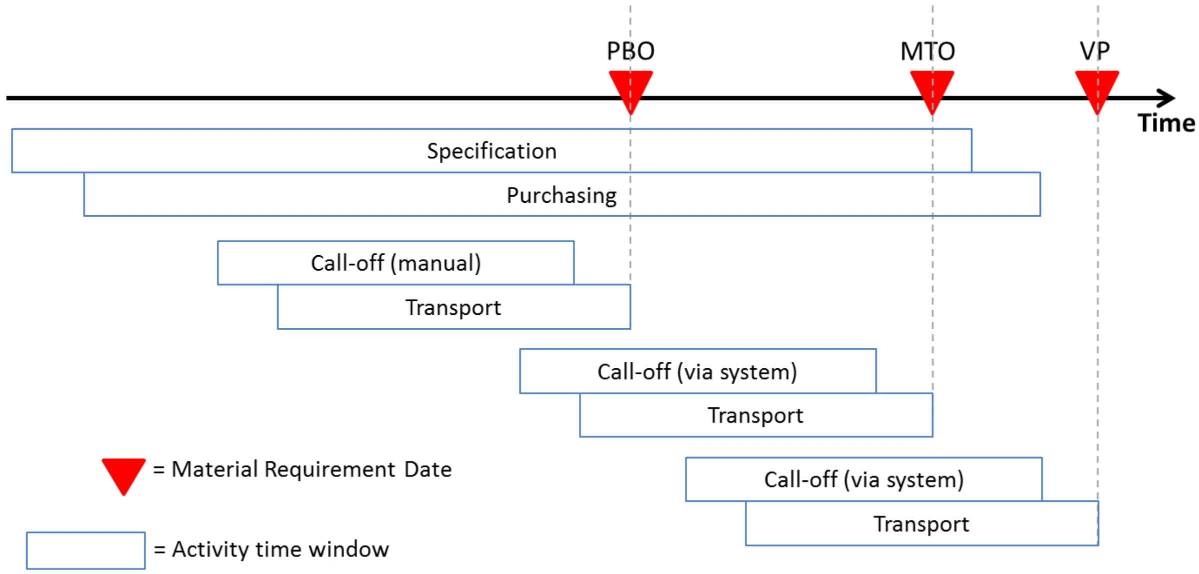

Figure 17 - Lead-time process view

These time-windows will vary in extent depending on lots of factors, e.g. the amount, size, and properties of parts that need to be transported to China. The times will vary from project to project and exact total lead-time is not measured for each specific part. Here it should also be mentioned that certain parts have considerably longer lead-times, such as; engines and gearboxes. These long lead-time parts is not showed in the figure 17 above but needs extra consideration in the whole process, since, changes on those long lead-time parts without consideration of downstream activities, will most likely cause the whole project to be late. What can be said about the lead-times is however; a part cannot be purchased until it is specified in the Volvo system, and a part cannot be called-off and transported unless there is a purchase order for the part. Additionally, even though lead-times for activities are uncertain, at a certain point in time the parts need to be transported from Europe to China. If a boat is to be used, the total lead-time from Europe to China is 12-13 weeks. That lead-time, contains activities such as; packaging, documentation handling, physical transport, and customs activities. It is a Volvo policy that production parts should, to as great extent as possible, be transported overseas with boat in order to save costs compared with the other, more expensive, air transportation mode.

If however, the time windows until Material Requirement Date (MRD) is less than 12 weeks the choices are; to be late, or to use airplane for the transport to China. In some cases Volvo chooses to have parts arriving late in order to save transportation costs. The needed parts could e.g., in some occasional cases, not be critical in order to start a required test and it does not matter if some parts are a few weeks late. That decision is taken by the "customer", who has the need for the test in the first place. More likely however, is that the parts are needed at the specific Material Requirement Date, and that leaves transportation to China with airplane. The total lead-time for airfreight is 1-2 weeks and by that, facilitates a bigger time-window for development and for preceding activities such as; specification, purchasing, and call-offs. Again, the trade-off of using air transportation is a higher price. The authors have not been able to get exact prices to compare the two different transportation modes, and a thorough total cost comparison, has not been possible to conduct. It is ambiguous how much late or stopped production cost, compared with a higher transportation price.

As a summary and a guide for the reader, the authors have compiled a table of the main takeaways from this chapter, what the reader should have with them when continuing reading the report. See table 6 below:

Table 6- Main takeaways from Chapter 5.2

Takeaways from chapter 5.2
• On an aggregated level, the process of getting material from Europe to meet Material Requirement Dates (MRDs) consists of the following activities; planning, specification, purchasing, call-off, supplier preparation, and transportation overseas.
• For the thesis scope, Verification Prototype (VP) parts, and Machine-Try-Out (MTO) parts have similar processes and will be treated and analysed in one process map.
• The Pre-Buy-Off (PBO) process is considerably different with support material sent from suppliers that are not the correct production suppliers and a lot of manual handling.
• Total lead-time for a specific part is hard to calculate and measure due to the fact that activities within the processes are done continuously, and not at a one single point in time.

5.3 Current processes

The report has now come down to the most detailed level of process mapping. The current situation, the “as-is”, will be described for the reader, for the processes of Pre-Buy-Off (PBO), Machine-Try-Out (MTO), and Verification Prototype (VP). Of course, the as-is process is not an end in itself but merely a mean, to identify risks that could increase the lead-time, and improvement areas that could decrease the lead-time in the whole process. The risks and improvement areas will be presented in chapter 5.4 and 5.5.

5.3.1 Pre-Buy-Off process

The process map in figure 18 below starts with the event; “Orderer has filled the AVB”. This means that the buying plant, the plant that has the need of an test, and consequently the need for test materials, fills in an list called “analyse and verification need list” (AVB-list). This list will be updated several times during the process and it will become more detailed and accurate the further in the process it goes. This list is a shared document that both, the buying plant and R&D in Gothenburg will use and update when information is acquired. Examples of information in the AVB-list are; Description of material need, Material Requirement Dates, Buying plant, Supplier, and much more, for a complete example of a total AVB-list see Appendix 3. When the buying plant has filled in their initial material need for a test series and sent that material need to Gothenburg, a joint meeting is held. This is the next step in figure 18, The Quality Leader for Test Objects (QLT), situated in Gothenburg, together with different manufacturing functions in the buying pant, decides on Material Requirement Dates for the needed extra materials in order to do Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) tests. The normal routine is backward scheduling, taking the starting date for the Verification Prototype (VP) build and see how many weeks in advance they need and can start the Pre-Buy-Off (PBO) and Machine-Try-Out (MTO) tests, to ensure that tooling and production process is correct in time for the Verification Prototype (VP) build. They take into consideration, the length of the Pre-Buy-Off (PBO) and Machine-Try-Out (MTO), which will vary from project to project and depend on e.g. the amount of new tooling required. Also, production constraints need to be considered, as explained in chapter 5.1. When those Material Requirement Dates have been decided, the Quality Leader for Test Objects (QLT) will update a total AVB-list with this information. Additionally, the QLT will add initial cost estimation for budget purposes.

The next activity for the Quality Leader for Test Objects (QLT) is to fill in order-sheets with the information from previous activities. The order-sheets are in excel format and is later used by Test Object Engineers (POBs) to specify the needed parts in Volvo test object system. An example of an order sheet can be seen in Appendix 4. At this point, a meeting is held within the R&D department in Gothenburg, between the Quality Leader for Test Objects (QLT), the Test Object Manager (TOM) who will manage the process later on, and the Test Object Engineers (POBs) who will specify the parts for the test series. One goal with this meeting is for the Quality Leader for Test Object (QLT) to explain the needs in the order sheets, what information has been given up to this point, and do the Test Object Engineers understand what needs to be specified later.

The second goal of the meeting is for the Quality Leader (QLT) to attain additional information about the test series. E.g. each new test series need to have a specific test ID, which is set by the Test Object Manager (TOM). With this information the Quality Leader (QLT) will create the need in Volvo test object system, but only on an aggregated level. The Quality Leader will create a “shell” if you will, with the test ID that contains information such as; variant, colour, left-hand or right-hand drive, engine, etc. The Quality Leader (QLT) basically creates an empty sheet in a Volvo test object system, that is called the test objects upper structure, and it should later be filled in with parts by the Test Object Engineers (POBs). When this activity is done, the Quality

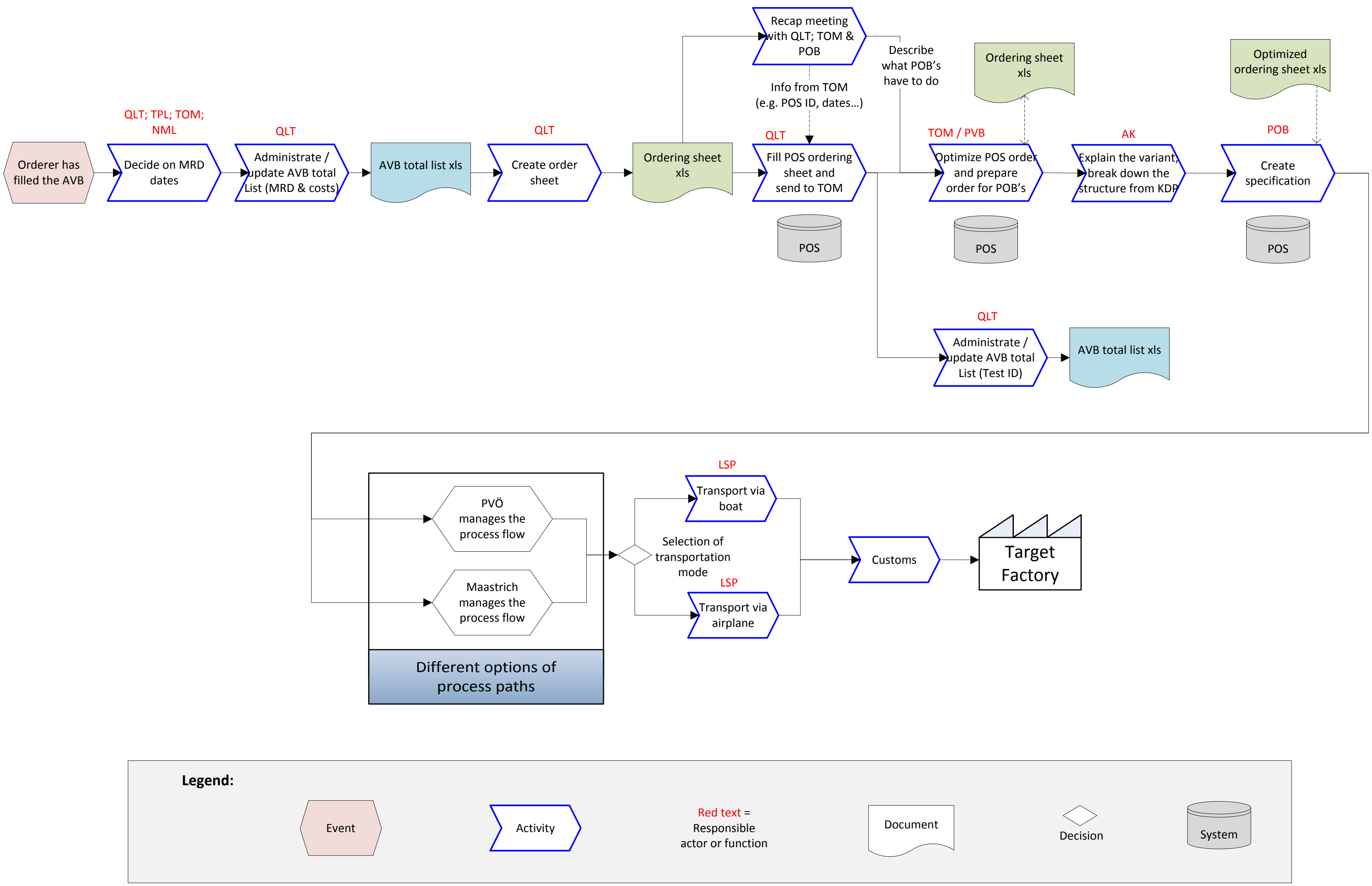

Figure 18 - Pre-Buy-Off process

Leader, "tics" in a box that the activity is done, and downstream activities can start their work. Additionally, the Quality Leader (QLT) will update the total AVB-list with the test ID information and upload the list to a database where the involved actors can find, and access it.

The next step in the process is that the Test Object Manager (TOM) will optimize the work of the Quality Leader for Test Objects (QLT). Making sure that all needed information is; entered, correct, and in the right format to fit the Volvo systems. The Test Object Manager (TOM) will optimize both, the information in the system, and the manually created order-sheets, e.g. the dates could be stated in the wrong format which would mean that downstream activities could be stopped due to system constraints. The final activity before the Test Object Engineers (POBs) can do their job is that an Article Coordinator (AK) breaks down the entered upper structure into part level. For a simplified example of the broken down upper structure, see figure 19 below:

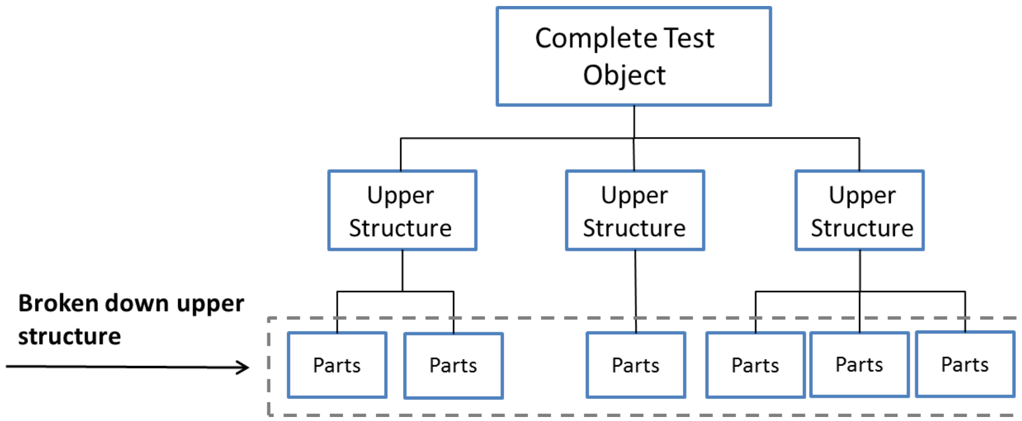

Figure 19 - A simplified illustrative example of how a test object structure is built up

Meaning, the structure defined in the Volvo system at this point is at high level and do not tell what exact part numbers that are needed, this is what the Article Coordinator (AK) does, either via systems or manually dependent what kind of parts that are needed, and how many different parts the test object consist of. Additionally, the Article Coordinator (AK) make sure that the defined structure can be specified and ordered without disrupting other processes or systems within Volvo. With the broken down structure provided by the Article Coordinator (AK), and the optimized ordering-sheets from the Test Object Manager (TOM), the Test Object Engineers (POBs) can start their work of specifying the complete test object in the Volvo test object system.

From this point and onwards is where the Pre-Buy-Off (PBO) process differ from the Machine-Try-Out (MTO) and Verification Prototype (VP) processes. First off, remember the fact that the correct production suppliers are not used in the Pre-Buy-Off process, this means that an intra-company purchase order has to be received from the buying plant in China to Volvo operations in Europe, and not to the correct production supplier directly. The European operation has to take care of ordering parts internally and then somehow, ship it over to China. There is no standard process for this, and it will vary from project to project. Which European operation that is responsible will also vary, no standard process exists. In this case nonetheless, with production material, the choices are; either the purchase order goes to the pilot plant in Gothenburg (PVÖ), more precisely the department project vehicles, or to a Knock-Down facility in Maastricht, Netherlands, where they will manage the process flow of ordering and sending support materials to China. This can be seen in the process map above, as the box called "Different options of process paths". The two hexagons in the box stating that, either PVÖ or Maastricht manages the process flow, the hexagons in themselves contains many activities but, as this is not a standard process, and it has been found out that this process is managed differently from project to project, a continuation of the current process map language would be very chaotic. Instead, the authors try to make a more understandable picture of the different options on how the process continues. A short shift will be made from linking activities and events with arrows, and instead showing facilities and how the material flow between them, in the process of sending material from Europe to China, see figure 20 below:

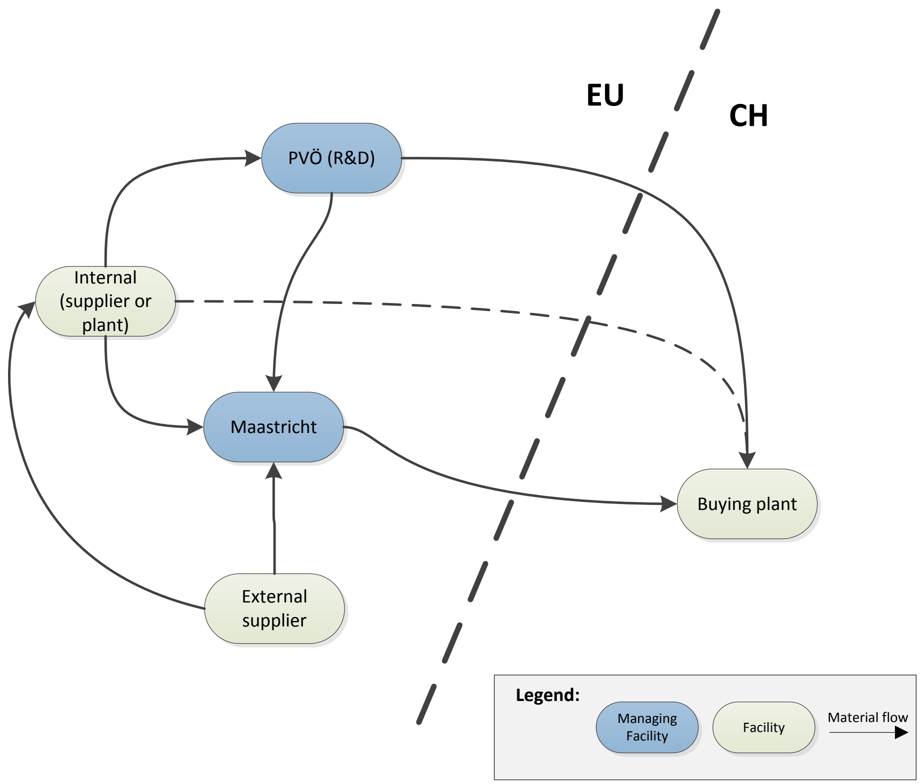

Figure 20 - Different material flow paths from Europe to China

The managing facility, either pilot plant in Gothenburg (PVÖ) or Maastricht Knock-Down facility will search where the needed parts are available. Since it is production parts that should be supported, it is almost always the case that, parts are available in internal storages; either in Pilot plant (PVÖ), Maastricht, European production plants (Gent and Torslanda) or internal suppliers. In some rare cases, the internal storages do not have the needed parts available and the external production suppliers will have to be contacted, but that is not the focus here, since, it rarely occurs for production parts. When parts availability is secured, the managing facility can send an inter-company order (ICO) to the facility where the parts are available and then send the parts onwards to China.

Here it should be mentioned that all material flow paths in figure 20 can happen, regardless of which facility that are managing the process. There are two main options from where the parts are shipped to China, namely; from the pilot plant in Gothenburg (PVÖ) or Maastricht Knock-Down facility. On rare occasions, the internal suppliers can also send parts directly to China, hence the dotted line in figure 20 going from internal supplier to the buying plant in China. Prerequisites for sending parts to China are: purchase order from buying plant, correct shipment documents, the buying plant has to have an approved import license (this requirement does not apply to all parts), and correct transfer price on the parts are needed. With transfer price means that, it is not allowed to only charge the part price, as is the case within the European Union. The transfer price has to cover all costs that has been induced into the parts, such as: material, labour, overhead, and administrative costs. Additional to those costs there has to be a mark-up of some percentages, due to tax regulations in China.

If all the material flow paths can occur, regardless of which facility that manages the process, does that mean that it does not matter who is responsible? Not quite, there are a few differences with having the pilot plant in Gothenburg (PVÖ) or Maastricht managing the process. Firstly, the amount of system support is different. The pilot plant (PVÖ) is a R&D operation and does not normally handle material planning and logistics, thus the work of ordering parts, creating shipping documents, organizing transports, and dispatching will be manual work. Meaning; searching for correct information, sending emails with orders, calling transport suppliers, and so on, in comparison with Maastricht who will need the same information about the shipment but in an earlier stage. When that information is acquired, Maastricht can load the information into their ordinary systems, which can automatically send out call-offs, print packaging labels, and informs transport providers that they should come and pick-up parts. Basically, both facilities have the same need of information in order to send parts to China, but the need comes in different point in time in the process, and Maastricht has about 50/50 split between manual work and system support. Secondly, Maastricht does not have access to the same information as the pilot plant in Gothenburg (PVÖ) has. There are certain test object systems, containing part information that is needed in the process of shipping parts over to China, and thus Maastricht has to ask pilot plant (PVÖ) for information if they are managing the process. Lastly, Maastricht is, as mentioned, already supporting other Volvo production plant in Asia, and has a big warehouse with production parts, thus making it more likely that they have production parts in stock, compared with the pilot plant in Gothenburg (PVÖ).

5.3.2 Machine-Try-Out and Verification Prototype process

As a point of departure the process map shown in figure 21 below is when the planning and specification phase is completed, corresponding to all activities up until and including “create specification”, in figure 18 in the previous sub-chapter 5.3.1. The preceding activities are almost the identical as for the process of Pre-Buy-Off (PBO). The start of the process map, “specification done for factory 36´” means that all production parts for the Verification Prototype, going to the production plant in Chengdu, have been specified in the Volvo systems. Factory 36´ is a code for the production plant in Chengdu for test series, and it is important in the specification activity to get that code correct in order for purchasing to place orders towards the correct target factory. There is two ways to the next event in the process maps, namely; parts that have been bought before by the Chengdu production plant, and parts that have not been bought before. If the part has been bought before to the Chengdu production plant, it will load directly into the factory systems in Chengdu, where the parts later can be called-off. With factory systems the authors mean, material planning systems, keeping track of inventory, sending delivery plans, and call-offs to suppliers.

If however, the parts have not been bought before this will show up in a deviation list that persons at the target factory are responsible for. This deviation list is forwarded to a purchasing coordinator that will distribute the not bought parts to a purchaser who then will negotiate the contract and place a new purchase order. A general directive from R&D is that purchase orders should be placed within three weeks after the specification is done. When all parts needed for the Verification Prototype has purchase orders, and the factory system in Chengdu is loaded, the event “complete car order in factory 36´” occurs. This is a crucial event, due to system constraints in the Chengdu production plant. If all parts for the complete Verification Prototype series are not available in the factory systems in Chengdu, they cannot call-off the parts automatically. This is due to the factory system, which only allow call-offs for complete cars, not single components, and a prerequisite is that all parts have purchase orders.

When the event, complete car order has occurred, delivery plans of needed parts can be sent out to suppliers. This however does not consider the extra need for material that the Machine-Try-Out (MTO) requires. This is where figure 21 is divided after the event complete car order, the Machine-Try-Out (MTO) parts can be seen as an “extra need” of the same parts that are already in the Verification Prototype (VP) series. As it is briefly explained in chapter 5.1, Machine-Try-Out (MTO) is mainly for body parts, and how many, complete or part of bodies that should be sent to the target factory is decided in collaboration with R&D in Gothenburg and the target factory. The specification for the Machine-Try-Out (MTO) parts are done in R&D in Gothenburg by a test object engineer (PVB) and entered into an excel sheet that is sent the production plant in Chengdu. In Chengdu they can load the factory systems manually with the extra need, and correct delivery plans can be sent out automatically to suppliers. E.g. the Verification Prototype (VP) series can consists of say 100 cars, and as an extra need for Machine-Try-Out, 20 bodies are required. Thus the delivery plan to the body supplier simply shows a need of 120 bodies instead of 100 but with different shipping dates.

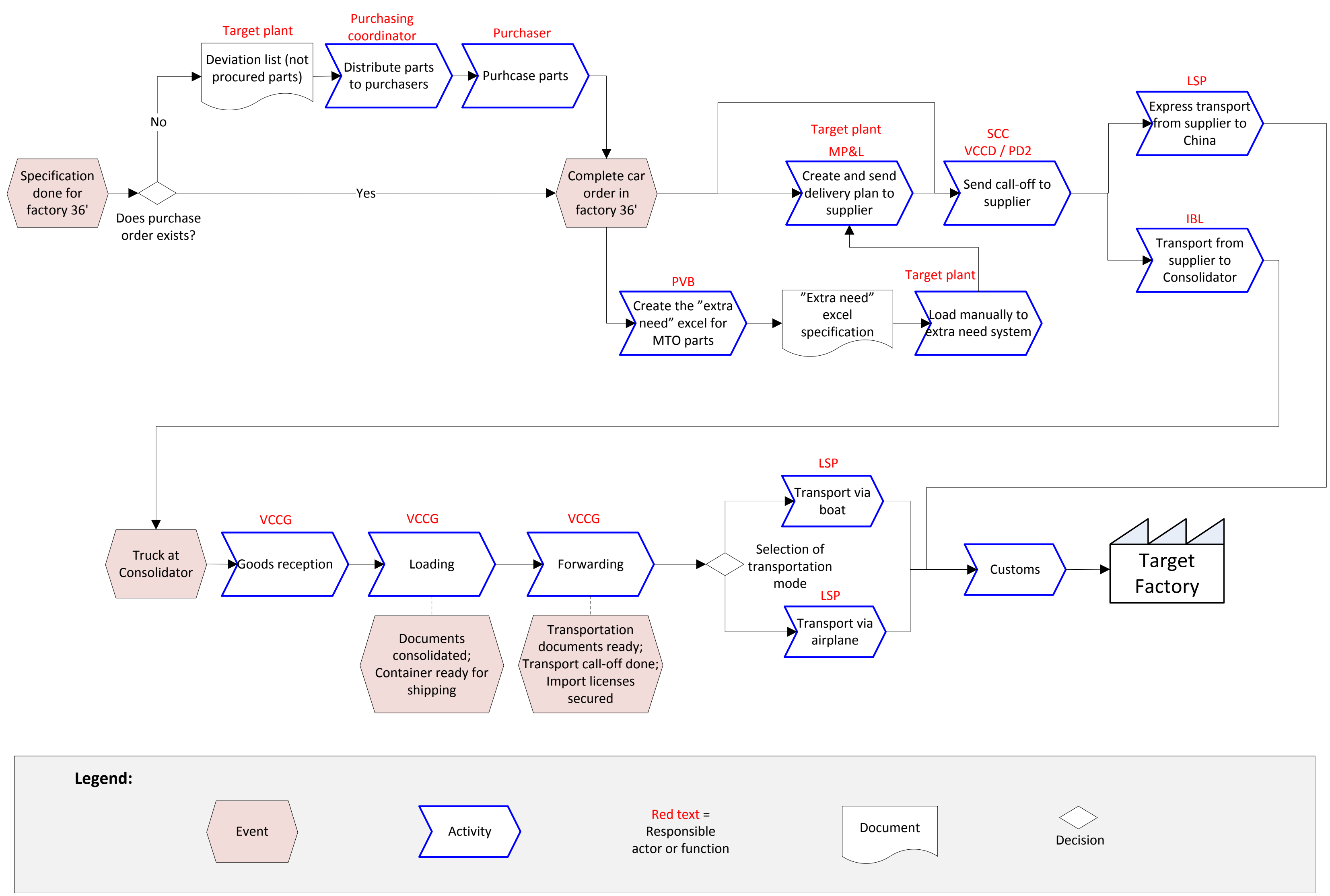

Figure 21 - Process map for Verification Prototype and Machine-Try-Out materials

The delivery plans and call-offs could go to local suppliers in China but since the thesis scope is production parts from Europe to China, the authors focus on this flow. Thus, the next activity in figure 21 is transportation from suppliers to either, a consolidator or a direct shipment to China. It should be said that, the direct transport alternative only happens when it is Volvos own internal production suppliers who are sending the parts. E.g. the body plant in Olofström, which is an internally owned supplier. It should also be said that this, direct alternative, is not the normal flow, the most commonly used alternative is to send the parts, via Inbound Logistics provider (IBL), to the Volvo Consolidator Centre in Gent (VCCG). Why the consolidator in Gent is used, other than gaining higher fill rates in the transport overseas, is because they are experts in packaging and documentation handling. China regulations are very strict in terms on how you pack parts, what documents is needed in the customs, and that knowledge is not easily obtained.

When trucks from suppliers are at the consolidator in Gent the first activity are goods receiving. Followed by a pre-loading activity, where a loading plan is made for the container and documents for the different parts in the container are consolidated. When the container is loaded and closed, the next activity in Gent is forwarding. In this activity, a call-off goes out to a transportation provider to come and pick the container up. All transportation documents have to be ready, and import licenses should be secured. From here the loaded container is either shipped to a harbour or an airport dependent on which mode that should carry the container to China. The lead-times are roughly 12-13 weeks, and 1-2 weeks respectively. When the container arrives in China, either by sea or air, extensive customs activities will take place before the parts are allowed in the country. At best, the customs activities take 1 week and when the container has cleared the customs it can finally be delivered to the target factory.

5.3.3 Summary of current state

A summary of the main takeaways from the current state are stated in table 7.

Table 7 - Main takeaways from chapter 5.3

Takeaways from chapter 5.3
• All three processes have the same activities up until, and including, specification.
• Laws and regulations for customs in China are strict and tend to change.
• Pre requisites for sending parts to China without having problems with customs regulations are; correct shipping documentation, correct transfer price, purchase order from buying plant, correct packaging, and secured import licenses when needed.
• After specification the Pre-Buy-Off (PBO) process has no standard routines on how, or who should manage the shipment of parts from Europe to China. Additionally, the correct production suppliers are not used.
• The Pre-Buy-Off (PBO) process contains a lot of manual labour without system support.
• The Verification Prototype (VP) and Machine-Try-Out (MTO) process have standard routines and system support.
• For Verification Prototype (VP) and Machine-Try-Out (MTO) the shipment to China goes through a consolidator in Gent, where expertise about packaging and shipping documentation exists.

With regards to laws and regulations for customs in China, there are a lot of different prerequisites that needs to be met before shipping parts to China. Without the correct shipping documents, correct transfer price, correct packaging, and import licenses the shipment will most likely be stuck in customs or be sent back to Europe, and the total lead-time will increase. For the Verification Prototype (VP) and the Machine-Try-Out (MTO), the consolidator centre in Gent manages the needed shipping information and packaging, whilst in the Pre-Buy-Off (PBO) process it could be either Maastricht Knock-Down facility or pilot plant in Gothenburg (PVÖ). It is especially hard for the pilot plant in Gothenburg to have the knowledge and experience of the needed prerequisites to ship parts to China, because shipping is not the pilot plant´ (PVÖs) core business. Additionally, customs regulation in China tends to change arbitrarily, which further complicates how the knowledge about needed prerequisites are acquired.

In the Pre-Buy-Off process, either Maastricht Knock-Down facility, or the pilot plant in Gothenburg (PVÖ) manages the process of getting parts to China. The responsible facility will vary from project to project, with no clear routines or standards for how this should be done. Additionally, the Pre-Buy-Off (PBO) process involves more manual work and operations when comparing with the Machine-Try-Out (MTO) and Verification Prototype (VP) processes, due to that the Pre-Buy-Off (PBO) process occurs earlier in the development process.

5.4 Risks of increased lead-time

In this section, the risks of increased lead-time will be presented, which were identified through the process view approach. As stated in the literature review, in this thesis, risks are treated as events or consequences that have an effect of increasing lead-time, which will jeopardise the possibility to meet the objective of building the test objects on time. The current state process was examined to find events or consequences that have an effect of increasing lead-time. Also, specific comments about risks from interviews were helpful to give hints for detection of risks.

After the risks were identified, they were organised into four different groups; knowledge risks, work process risks, pricing risks and IT systems risks. Also, it was seen that some risks were general to all series, but some were specific to Verification Prototype (VP), Machine-Try-Out (MTO) or Pre-Buy-Off (PBO). Different risks identified in the process view can be seen in table 8 below. If there is an indication to a series in the table, the risk is specific to a certain series, otherwise the risk is considered general to all series.

Table 8 - Risks of increased lead-time

Knowledge	Work process	Transfer pricing	IT systems
Documentation	Insufficient information quality	Difficult to set the transfer price (PBO)	Purchase order not placed due to purchasing system setup
Customs regulations	Unclear responsibilities between actors	Incorrect transfer price (PBO)	Losing information about parts due to different information system setup (PBO)
Packaging (PBO)	Shipment documentation not ready		
	Inter-company order not released before shipment (PBO)		
	Parts not available at internal storages (PBO)		
	Complete car order not ready in factory systems (MTO & VP)		

All different risks will in detail be described below. Firstly, it is defined where the risk occurs in the process. Secondly, a description what does the risk mean is presented and lastly, a motivation why is it a risk is argued.

5.4.1 Knowledge risks

Knowledge risks are derived from actor's lack of knowledge or understanding of a certain area.

Knowledge about documentations

The lack of knowledge regarding different documentations is a general risk for all of the test series. It could occur in every step, where actors have to deal with documents that are necessary for the process to flow without problems. Especially critical are the documentation knowledge issues in the packing and transportation steps of the process. For example, when the required documents are not prepared in the right way, the materials could get stuck in customs. Also, when there is lack of knowledge in the documentation area, it means that the actor who has to prepare the documents has to gather the knowledge from somewhere else, and this gathering activity adds up lead-time. In a worst case scenario, it might even be necessary to move the materials through a longer route, since some facilities are not capable of preparing the correct documents. The documentation issue is especially critical, because sending parts from Europe to China requires numerous documents to be correct (see appendix 5 for list of required documents).

Knowledge about customs regulations

The risk that materials might be stuck in customs due to lack of knowledge regarding customs regulations is a general issue for all the test series. This risk can occur in activities, where materials are handled for transporting them to China, as well as in activity steps where the initial information about the parts is created. If something is done not accordingly to the custom regulations, the materials will be stuck in customs and this would add up to the lead-time. For example, there are specific rules how to pack and send the materials to China. Another example would be the need to have the import licenses for parts that demand it. Also, if there is a problem with only one part in a shipment that contains hundreds of parts, the whole shipment will be retained in the customs. This means that all the actors who are responsible for sending the parts have to do their work correctly.

Knowledge about packaging

Not knowing how the materials should be packed is a risk in the Pre-Buy-Off (PBO) series process. The reason why this risk does not occur in a considerable amount in Verification Prototype (VP) and Machine-Try-Out (MTO) series, is that in these series the parts are supplied from the correct supplier and the materials flow goes via the standardized route, i.e. through the consolidator in Gent. The Gent consolidator has experience and knowledge in the packaging area, and therefore, the risk does not exist. But since Pre-Buy-Off (PBO) material does not have a standardized route, materials could be shipped towards China from different locations; from pilot plant in Gothenburg (PVÖ), Maastricht Knock-Down facility, or internal supplier or plant. The Maastricht facility possesses the packaging knowledge, but this is not the case for pilot plant in Gothenburg (PVÖ) or for internal supplier/plant. This means that if the materials are sent from these locations, there is a possibility that the packaging is done incorrectly and the goods will be stopped in customs. Additionally, if there is not good knowledge in the area of packaging, the activity of packing might take unreasonably long time.

5.4.2 Work process risks

Work process risks are related to situations and circumstances that affect how well the activities can be carried out.

Insufficient information quality

Insufficient information quality risk can occur in all activities of the process that have some kind of information input and/or output. With insufficient information quality, the authors mean that; information could be missing, the information could be incorrect, or the information could be late. This would add up lead-time because, this insufficient information needs to be gathered by downstream actors in the process, thus causing inefficiencies in their activities, by e.g. extra meetings, phone-calls, or email conversations. Additionally, if the needed information to perform an activity is late, the process cannot continue, thus extra lead-time has been induced in the process. A concrete example can be found in the planning phase of the process. The first AVB need that is filled in by the orderer, see figure 18, is often lacking in information and the Quality Leader for Test Objects (QLT) need to have an extra meeting with the buying plant to clear out what need the buying plant really has. Another example is the ordering-sheets, filled in by the Quality Leader (QLT). As explained in the current state, a meeting takes place where the Quality Leader (QLT) has to explain the needs in the sheet for downstream processes, if the information was correct from the beginning, this situation may not be necessary.

Unclear responsibilities between actors

The risk of unclear responsibilities between actors surfaces when the activities within processes change from one actor to another, or when multiple actors have responsibilities in the same activity. E.g. who should make sure that the correct information is given to perform an activity, or that all information needed in a shipping document is correct. Even though the Test Object Process is owned by R&D, there are a lot of department and functions who perform the activities, and the lack of clear responsibilities increases the risks of increased lead-time.

Shipment documentation not ready

At the point in time when the parts should be transported to China the risk of not having documentations ready can occur. The number of needed documents is substantial and the flow of documents is complex, see figure 22. With many actors involved, and a lot of information that needs to be in place, there is a big risk for documentations to not be ready, which will stop the process either at the shipping or, even worse; it will get stuck in the China customs where a whole container can be hold up, even though there are only one documentation mistake regarding one part in the total shipment. For a full list of needed shipping documents, see Appendix 5.

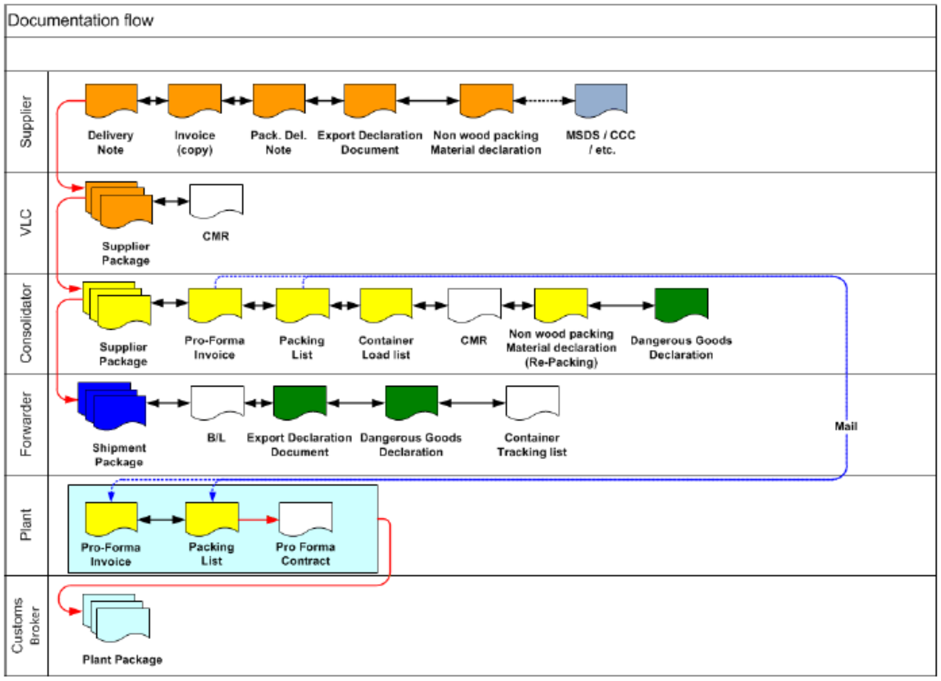

Figure 22 - Documentation need for shipping parts to China (Volvo Business Management System)

Parts not available at internal storages

Parts not available in internal storages could happen in the Pre-Buy-Off (PBO) process, when either pilot plant in Gothenburg (PVÖ) or Maastricht, are looking where parts are available. In that case, external suppliers will have to be contacted to produce parts, and that will increase the process lead-time. It should be mentioned that this is not normally the case for production parts, but it still a risk of increased lead-time.

Complete car order not ready in factory system

The risk of not having complete car orders ready in factory systems could arise in the Machine-Try-Out (MTO) and Verification Prototype. This could occur if; specifications are not done in time, or purchase orders are not placed in time. In the process map in figure 21, the complete car order is a prerequisite for the factory system to send delivery plans and call-offs automatically. If that is not the case, manual ordering has to be done, similar to the Pre-Buy-Off (process). Which means that; no standardized process is in place, there is no clear path for materials to flow, pricing issues arises, and Inter-Company Orders (ICOs) needs to be sent. Basically it gets hard to manage the process, and it is crucial that all preceding activities happens in time so that the complete car order can be received, and loaded into the factory systems in the Chengdu production plant.

Inter-Company Order (ICO) not released before shipment

In the case of Pre-Buy-Off (PBO), the buying plant in China has to send a purchase order to the managing facility in Europe, called an Inter-Company Order (ICO). For company policy and legal reasons, this Inter Company Order has to be received before the managing facility in

Europe can send the parts to China; currently that has not always been the case. Since the business set-up in China is relatively new, and previous shipments of Pre-Buy-Off (PBO) materials have been few, this issue about Inter-Company Order (ICO) has not been known to some actors in the managing facilities in Europe and China. Consequently, the lead-time could increase since the operations in Europe have to wait to receive the order from the buying plant in China, or the process will be stopped because an order has not been received, and thus policies and laws will be broken if the parts are shipped to China without the Inter-Company Order.

5.4.3 Transfer price risks

The transfer price risks relates to the importance and difficulties to set the correct price, when shipping parts to China.

Difficult to set the transfer price

Transfer pricing issues occur in the Pre-Buy-Off process, when the invoicing price, to the buying plant in China, needs to be set. As explained earlier, it is not enough for European Volvo operations to only charge the material cost when selling parts to China operations. Instead all induced costs in the parts need to be accounted for, and tax regulations require additional percentages to be added to the price, this total price is called the transfer price. The transfer price, as such, is not hard to calculate; material costs are shown in the contracts from suppliers, other costs can be drawn from budget calculations, and it is the tax-departments job to know the percentage mark-ups that needs to be added to the price. An intercompany controller at a financing department should have this information. However, since there is no standard process for the Pre-Buy-Off (PBO), there is no single actor responsible for setting this price, and if e.g. the pilot plant in Gothenburg (PVÖ) is managing the process, there is no person who knows about this financing information, thus making it hard to set the transfer price, and time consuming to find the right information.

Incorrect transfer price

If the transfer price is incorrect, there is a big risk that the shipment will be stopped in the China customs and increase the process lead-time. This could occur in Pre-Buy-Off (PBO) process when there is no one responsible for setting the transfer price, thus action needs to be taken to find the correct information, which can be faulty if the knowledge about transfer price calculation is lacking.

5.4.4 IT system risks

The lead-time could be increased due to IT systems setup, which create situations, where mistakes could be done, or do not allow the process to flow as smooth, and efficient, as it could have if all systems within Europe and China operations, were integrated with each other.

Purchase order not placed due to purchasing system setup

The risk of not placing purchasing orders due to purchasing system can only have one supplier per part number and plant arises in the transition from Pre-Buy-Off (PBO) process to Machine-Try-Out (MTO) and Verification Prototype (VP) processes. For the Pre-Buy-Off (PBO) process, as mentioned several times, the suppliers are not the correct production suppliers. This means that when the Pre-Buy-Off is done, and support material no longer is needed from the European support suppliers, the purchasing department needs to negotiate new purchase orders with the correct production suppliers. The tricky thing is that, the purchaser will not see that in their purchasing queue if the old support suppliers already have a contract for that part number. The purchaser needs to get information from R&D that the support supplier is not the correct production supplier, and the purchaser has to manually delete the contract with that supplier, in order to set-up a new contract, with the correct supplier. The risks for increased lead-time here are two-folded; one is that, the information that a new supplier is needed never gets to the purchaser, and then purchase order will not be placed and the factory systems cannot be used later on in the process for call-offs, which will increase the amount of manual work and therefore man hours. The second risk of increased lead-time is the fact that, the purchaser has to put in additional manual work hours to delete the existing contract.

Losing information about parts due to different information system setup

The risk of losing information about parts due to not having the access to the same information systems in European facilities is a risk in the Pre-Buy-Off process. If the pilot plant in Gothenburg (PVÖ) manages the process after specification is done, they do not have access to the packaging and inventory systems as Maastricht uses. Meaning that packaging information, labelling, and shipping documents cannot be created automatically, instead manual work needs to be used to gather this information, those efforts will increase work hours and thus it is a risk of increased lead-time. Moreover, transferring information manually creates a chance for human errors to occur and if false information is handed over, then eventually it could stop the process at some point and lead-time is added. On the other hand, if Maastricht manages the process, they do not have access to the same test object systems as the pilot plant in Gothenburg has. The test object system contains needed part information and Maastricht has to ask for that information manually, via email or phone call. This extra manual activity also has the risk of increasing lead-time in the total process. Additionally, Maastricht systems only allow production part numbers to be put into the system, which is the scope of the thesis. However, in the operations of the R&D department in Gothenburg, test objects usually include both production parts, and pre-series part that have not been in production cars yet. This should not be a problem for this thesis, since its scope is about production parts, but if Maastricht is managing the process they often get lists of needed parts that contain both production parts and pre-series parts. Thus, the lists need to be sorted, to exclude pre-series parts, in order to use the Maastricht system, and that will demand manual work, which creates a risk where some parts could be missed or overlooked. Manual work itself adds to the lead-time, but the situation when parts are lost during manual work increases the risk of increased-lead time.

5.5 Improvement areas

In this section, the improvement areas for lead-time reduction, that are specific to process approach, will be presented. The risks presented in the previous chapter were, as explained, treated as events or consequences that have an effect of increasing lead-time, which will jeopardise the possibility to meet the objective of building the test objects on time. This basically means that mitigations of those risks would stabilise the process and ensure that the test objects are built on time. The improvement areas however, should be looked upon as areas that could reduce the lead-time from a stable state, meaning potential for further lead-time reduction, not only to ensure that test objects can be built on time in the current process. However, some improvement areas might have a mitigating effect on the risks presented in the previous chapter.

The improvement areas are presented in three parts. Firstly, improvements for the process from the creation of verification and test need until specification creation. Secondly, improvements for Pre-Buy-Off (PBO) process from the creation of specification to material delivery to target plant; and lastly, same frame for Machine-Try-Out (MTO) and Verification Prototype (VP) processes. The discussion about improvement areas will be taken further in chapter 7, where the improvement areas are treated jointly with organizational view.

Process from verification and test need to specification

When looking at the current process of creating the need and specifications, activities have been identified that do not add value. The process should be investigated to find ways how would it be possible to eliminate the need to have these activities. Such activities are extra meetings to clarify information, administrations of information lists, and correcting and optimizing documents that have been created wrongly by another actor.

One improvement area would be to develop further the AVB total list and the ordering sheet, so it would be possible for the Test Object Engineers (POBs) to get the right and detailed information about the parts from the files. If the ordering sheet will contain the right amount of information, then there would not be a need to do an extra meeting to clarify the information. Another improvement area is to educate the actors regarding how the information should be inputted to the documents. Currently there are several errors in the documents; therefore, one actor has to check the information over and fix the mistakes and optimize the documents. This kind of activity is adding up to the lead-time and should be eliminated.

As it can be seen, then one additional reason for having extra meeting is that Test Object Managers (TOMs) are the persons responsible for creating Test IDs and they have to forward this information to Quality Leaders for Test Objects (QLT), so they can proceed with their activities and update their information lists. As it was understood for the authors, then the creation of Test IDs follows a specific rule and any actor who has knowledge about these rules, should be capable to create Test IDs. Therefore, improvement would be to educate Quality Leaders for Test Objects (QLTs) in creating Test IDs and shifting the responsibility of creating it to Quality Leaders for Test Objects (QLTs) in earlier phases of the process. This means that this information would be created exactly in the point, where it is firstly needed (e.g. when AVB total list is created), rather than going back to update the files, when the Test ID is created. This would also mean that the need for having clarification meetings could be lost.

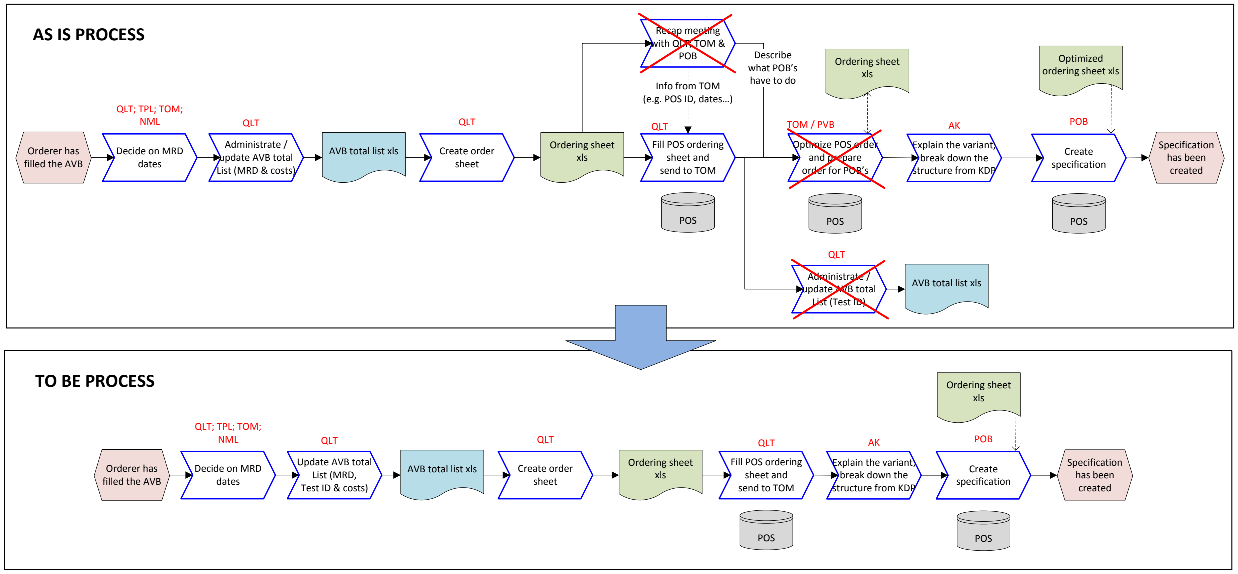

Figure 23 – "As is" and "to be" process from verification & test need to specification

The impact of these improvements would be that there would not be a need for clarification meetings, fixing the mistakes in documents would not be necessary, and administration and updating of previously created information sheets would not be needed. See figure 23 how the process would change, if the improvements are carried out. It can be questioned how much time actually will be saved when these activities will be eliminated, but these changes would make the process simpler and smoother. The impact of having a smooth, clear and defined process, where actors are carrying out the tasks with necessary quality will create a ground for a process that has potential for further lead-time reduction. If the waste activities are eliminated, then it will be possible to develop and optimize further the value adding activities, therefore, it would set the scene to ultimately reduce the process lead-time even further.

Additionally, it must be mentioned that from a lead-time perspective, it is important to ensure the quality of initial process steps. These activities discussed above are creating the foundation for later activities in the process. If the planning and specification activities are done in a poor quality, extra work has to be done later to fix the created problems. Reworking and problem fixing are adding up to the lead-time and in worst case, when a problem in the process is identified in late steps, the rework will be very costly in terms of extra lead-time. Waste activities create confusion and complexity and hence, increase the chance of errors and therefore, decrease the overall quality of the outputs. Consequently, it can be argued, that if waste activities are removed from the process and if the process is standardised and smooth, then the quality of the outcome from the process will be better. This will be one possible outcome from the improvement suggestions.

Pre-Buy-Off (PBO) process from specification to material delivery
As it was seen from the current process description, then there is no standard who will manage the whole process of calling-off the material, organizing the invoicing issues, organizing the transportation and documentations, and keeping track of the parts status, i.e. the process of making sure that right products are sent on right time from Europe to China. As it was seen, then there are regularly two options – either pilot plant in Gothenburg (PVÖ) or Maastricht Knock-Down facility will take this responsibility. This means that the material might flow through very different channels and this kind of uncertainty causes unrequired confusion and extra planning. Moreover, when the processes of managing the material flow as well as physical material flows are not standardised, then it is not possible to measure the lead-time for the process. If it is not possible to measure, then it is not possible to improve the lead-time. On the other hand, standardisation could lead to loss in system flexibility, but the authors are on the standpoint that the potential benefits from standardisation will overweight the lost flexibility. The reason is that both facilities have still option to call-off materials from all necessary locations. Hence, the authors would like to highlight an improvement area of standardising the material flow process in order to reduce the lead-time.

An obvious question would be; which location should take up the responsibility and how should the material flow between the facilities. To help in making this decision, both options have to be evaluated. The risks introduced in the previous chapter provide good input to this evaluation.

Firstly, when examining the pilot plant in Gothenburg (PVÖ), then it draws out that they do not possess the knowledge of packaging that is needed for shipping parts from Europe to China. Pilot plant in Gothenburg (PVÖ) has a small outbound logistics area, but they are not specialised in sending out parts to China. Secondly, logistics is not the core business for pilot plant or R&D department, who are managing the processes there. One problem induced from this is the lack of expertise in managing these processes (e.g. how the shipping documents should be prepared), and another problem is that when dealing with logistics, then they have to take away resources from their core business. This would possibly put under risk if the expected goals and performance objectives set on them will be achieved. From a positive side, pilot plant in Gothenburg (PVÖ) is very close to the actors who have been involved in the development, need creation, and specification of the part. This could mean that it is easier to reach the source of information if necessary. Also, pilot plant in Gothenburg (PVÖ) has the access to the necessary information systems regarding test objects, what would be necessary to ship parts.

Strong argument supporting Maastricht facility option is that their core business is packaging and logistics and they have the experience and knowledge in sending parts to China. This means that the knowledge risks of packaging, documentation and customs would be reduced. Furthermore, they have extensive experience in packaging and standardised processes for packaging have been set in place and implemented. Also, since often the packaging requires using packaging suppliers or service providers, then Maastricht have these connections already established. From the negative side, though, is the fact that Maastricht does not have access to all IT systems and they have to collect the needed data from different sources. Also, there is a slight risk that urgent shipments might not be treated in quickest manner due to lack of responsibility feeling.

These motivations have to be taken into consideration when making the decision which facility should take the responsibility. After examining both options, then the authors would choose the Maastricht facility option. The issue of core business weights up the system constraints, though, these constraints should be dealt with. One option would be to map down exact information, what Maastricht needs for their operations and then standardise the information sharing process, so it would be as efficient and with high quality as possible. The change in the process map can be seen in figure 9.

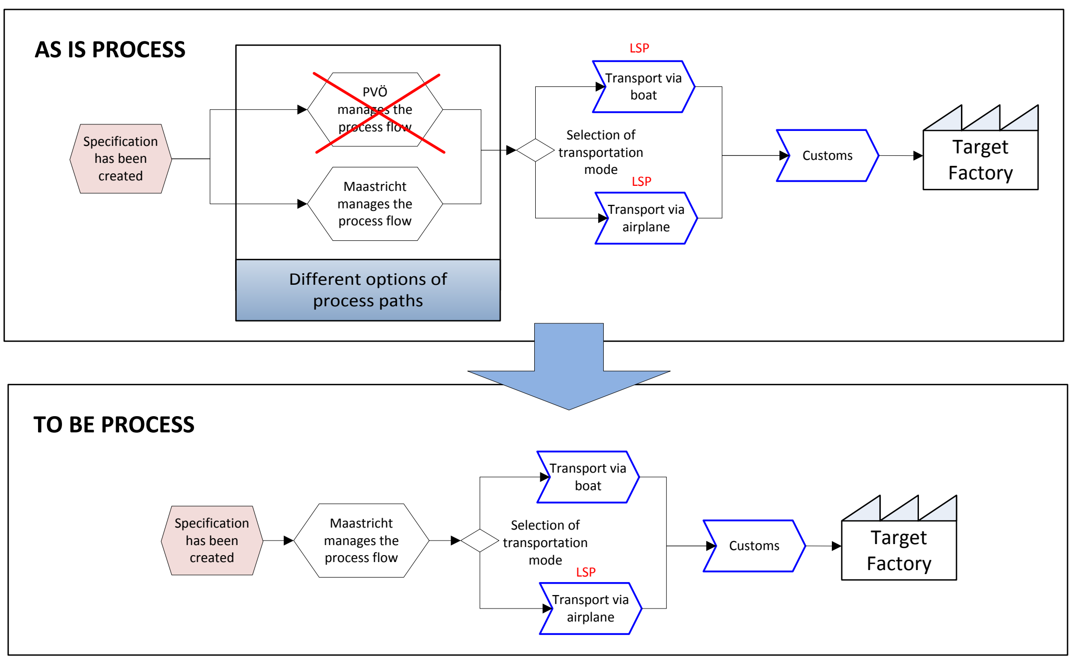

Figure 24 - "As is" and "to be" process for PBO series

Since the activity "Maastricht manages the process flow" from above figure is on aggregated level, and then this does not exemplify the suggestion to the reader too much. For this reason, the material flow map is presented as well below in figure 25. The red lines indicate the flow paths that will be eliminated and the black arrows stand for flow paths that will still exist. As it can be seen, then the standardised management of flow and standardised flow paths will clear up the material movements significantly.

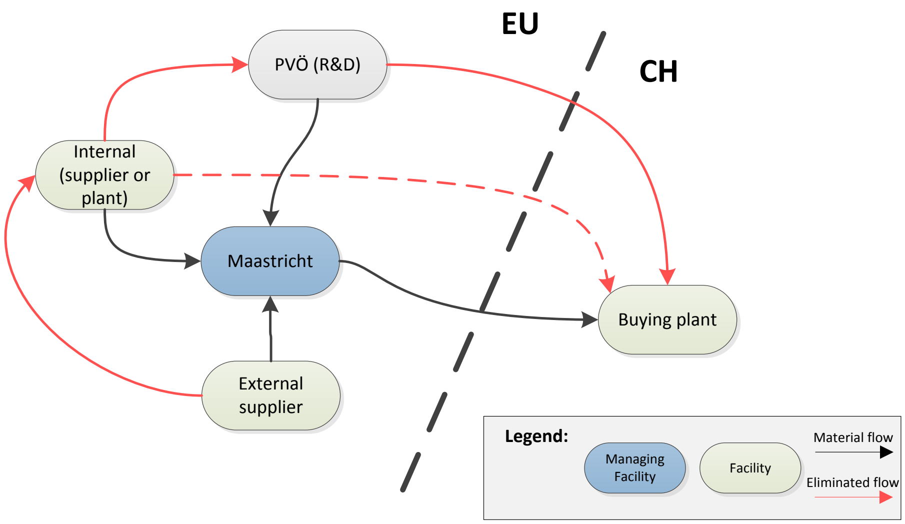

Figure 25 - "To be" material flow from EU to CH in PBO series

Machine-Try-Out (MTO) and Verification Prototype (VP) process from specification to material delivery

With the scope and the assumptions that have been made in this thesis, examining the Machine-Try-Out (MTO) and Verification Prototype (VP) process from the creation of specification to the point, where material is delivered to the Chinese facilities, the authors cannot see any major problem areas with the process build up. The process is standardised and if all the actors fulfil the tasks set on them, then the process should work well. Therefore, there are no specific improvement suggestions to improve the process map. Nevertheless, in order to reduce the lead-time, then all the actors have to focus on their tasks and they have to deliver what is needed on the time, when it is needed. Work organization and working culture are issues that cannot be visually seen from the process map, but they are important in having good workflow. Hence, the improvement areas to consider are directed to increase the working culture and working approach.

One area to improve is that all the actors understand what they have to do and how their work and decisions impact other actors. It is also important to better the interface between actors to match the outputs from one activity to the required inputs to the next. Also, communication between actors is important to make the process work faster. Very important is also to highlight the respect for deadlines, so process will not be stopped if one actor has not finished his work on time.

The authors have seen that previously described areas are especially important in the interface between the engineers and purchasers. Purchasing activities take usually long time to complete and to secure the parts; information has to be sent to suppliers as early as possible. As it was seen, then often purchasers postpone the start of activities, since they do not have information regarding the readiness of the part specification and design. The reason is that if, later on, changes might occur, purchasers have to renegotiate the deals. Obviously renegotiations should be avoided, but this situation sets under risk if the parts are purchased before they are needed and if the capacity at supplier site is secured. Therefore, if the communication between engineers and purchasers would be improved, and the overall information would be more visible for actors, then actors could plan their activities more efficiently accordingly. Information visibility is beneficial not only to purchasers, but also to other departments.

Another improvement area would be to develop and integrate the IT systems. This could automate many activities and fasten the data exchange between systems and actors. Also, it would be possible to make the systems better support the current activities and increase process flexibility by reducing the rigidness. Though, investments in IT systems are very expensive and therefore, very probably the possible gains from the investment will not overweight the investment itself. But still, this is one improvement area and it can be looked into further in the future.

6 ORGANIZATIONAL VIEW OF GETTING MATERIALS FROM EUROPE TO CHINA

In this chapter, the organizational view of getting materials from Europe to China is presented. The organizational view is looked upon from the perspective of complexity. Firstly a chapter of empirical findings is introduced in order to provide the reader with a general understanding of the organization in terms of different perceptions, objectives, and roles between departments. Secondly the complexity drivers are described and discussed in the context of Volvo Cars. Thirdly, possible improvement areas of supply chain visibility, cross-functional teams and front loading are introduced and discussed. The chapter ends with a discussion how these concepts can be used to deal with the defined complexity drivers.

This chapter takes under investigation the four complexity drivers that are described in the literature review. As it was stated in the literature review, when the company is able to manage the complexity drivers, then this would lead to higher efficiency of processes and ultimately reduce the total lead-time. Therefore, the purpose of this chapter is, after the empirical data is introduced, to put the complexity drivers in the concept of Volvo Cars and thereafter, identify possible measures to manage the complexity drivers. The complexity drivers are risks of increased lead-time by themselves and the managing measures can be considered as improvement areas to reduce the lead-time.

6.1 Empirical data

Interviews have been conducted with people from various departments, who are involved directly or indirectly in the processes of getting material between Europe and China. The purpose of the interviews has been to create an understanding of the organizational environment and determine if there exist contradictions regarding how operations are done, and what problems that exist in the operations as they interact with each other. The interviews have been conducted on both management and administrative level in order to get as accurate data as possible. The interviews has been focused to what kind of problems the interviewee perceives in the test object process. Since the interviews have been semi-structured and some questions to the interviewees have been quite open, some answers range outside the scope of the thesis. It is not the intention of the authors to dwell on topics which is out of the thesis scope but some useful insights could still be drawn regarding the organizational perspective related to the thesis scope,, as will be seen later in this chapter.

Interviews conducted at R&D imply that the department is focusing on lead-time. This has both been expressed explicitly as managers has stated that lead-time should be emphasized, and by interviews at administrative level where interviewees often mention lead-time as a response to open questions regarding the process flow between Europe and China. Several persons at the R&D department are concerned about risks of increased lead-time and address purchasing as an issue regarding factors that add up to lead-time. A problem with orders sent to the purchasers is the fact that they sometimes tend to be placed very late, and that persons responsible for these orders occasionally have to spend time contacting the purchaser in order to secure that the order is placed. Another concern that exists within R&D is that orders should be placed to secure capacity at the supplier site, meaning that orders should be placed as early as possible to book capacity at the supplier site, and since R&D are concerned about purchase orders not being placed this raised the concern about increased lead-time.

Regarding the communication between R&D and purchasing there exist a middleman function who has the contact between the departments. A person from the department of Pre Production Management runs this function and the responsibility of this person is to secure that the purchasers places the orders in time.

Persons at the purchasing department highlight several issues that can have a direct impact on the risk of increased lead-time. One of the things that are brought up is the fact that the purchaser has a certain purchasing queue that he/she processes before a part can be called-off. If that queue is big there might be a risk that the purchaser cannot place the parts within the required time. Although the purchaser can prioritize important purchase orders; purchasers are in first hand focusing on production material and lowering purchase cost. Purchasing highlights the fact that the pre-production material does not get the same attention as the production material where they know what is going to be built. However this situation does not apply for the pre-production material, as they feel "blind" to what happens in the prototype series.

A desire that has been requested is that the Test Object Engineer (POB) informs the purchasers in advance in order for them to prepare the work. If the purchasers for instance could get an acquisition list 10 weeks before the test car needs to be built, then they could actively go to the Test Object Engineer (POB) and ask what they needs for their cars. If the buyers then have the acquisition list; knowing that the various cars need to be build a certain week. They also know that the acquisition list has to be followed by a purchasing order.

Regarding late changes of specifications the purchaser knows by experience that some part are more inclined to involve more changes than other components, e.g. cable harness which is the "slave" to many components and is prone to change if any other component are changing. If the purchaser is placing the purchase-order for e.g. cable harness, he is contacting the supplier and agrees on a price. After that, the buyer is creating a purchasing order which is put it into the system. If R&D requires a new change within a week, the purchaser has to start all over again.

If the purchaser by experience knows that the cable harness will change e.g. five times between release of the Bill-Of-Material (BOM) to the last moment when the cable harness need to be bought; the purchaser want to wait with placing the order to the very last moment. This is done in order to save cost (that will be induced due to the changing process) and time for placing the orders, as well as the fact that he want to keep a good contact towards the supplier.

Purchasing states that they do not think that the Test Object Engineer (POB) always are aware of the consequences of all late changes, and thereby not understand why the purchaser is acting the way he does.

Regarding what can be done to improve the situation, purchasing implies that much things can be done to improve the situation. Especially when it comes to late changes, where specifications should be frozen as late as possible and if changes should be done after that, they should be well justified. Purchasers states that they do not think that people who initiate changes in the specification, always are aware of the consequences of the changes, and the lead-time and criticalities they contribute to. This statement is also supported by interviews with Material Planning & Logistics (MP&L) who (when it comes to changes in distribution) argues that changes are good, but you should be aware of the fact that someone else might have to take the consequences for them as well.

Comparing the different perspectives of the different departments, it can be concluded that they often tend to shift the responsibility for problems to other departments. Another aspect that has been recognized during interviews with planners is problems with collecting information when planning conditions changes. As the conditions changes, planners often have to ask around for the information they need. Besides this aspect, it has also been highlighted that planners occasionally order more than they should, e.g. as they by experience know that parts of the specifications are inclined to be scrapped for any reason. Examples can be of orders for testing cars in Hällered test track, crash test etc. Although this situation has been improved over the years it still prevails in the organization according to interviews.

6.2 Complexity drivers

The complexity drivers mentioned in the literature review are *variety/uncertainty*, *number of communication channels, ignorance* and *strategic objectives.* In this section, the complexity drivers are evaluated how they affect the organization at Volvo. The relation between the complexity drivers and the context in Volvo is illustrated in the figure 26 below. The figure illustrates identified contextual causes of complexity drivers in the studied Volvo Cars context.

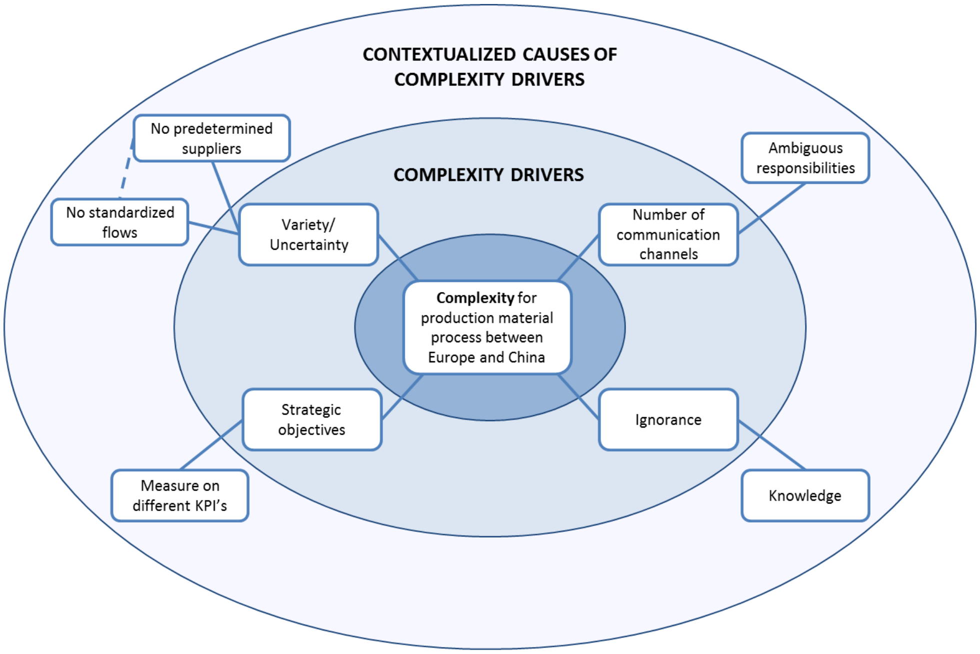

Figure 26 – Complexity drivers in Volvo Cars

Below the specific complexity drivers and their relation to the identified causes in Volvo are discussed.

Variety/uncertainty

Relations between *variety/uncertainty* and the process of getting material from Europe to China refers e.g. to the absence of standardized flows. When there exist a need for material in China, material will be sourced from the first supplier that is able to supply. As this supplier can be random and is not defined as a predetermined supplier, this will add to the variety and uncertainty in the flow. As the choice of supplier can vary from time to time, this will have an impact in the ability to establish good conditions for continuous improvement and elevation of problems.

Number of communication channels

The number of communication channels as a complexity driver refers to the fact that ambiguous responsibilities may arise as no standardized flows are used and individuals need to look around for information, which creates more interactions and thereby, more potential communications channels, which drives up the complexity.

Examples of these ambiguous responsibilities may arise as changing conditions occur and when it becomes unclear of who has the responsibility for a particular issue. During such circumstances it has emerged that when people have to look around for information; the communication often is personalized. This adds to the complexity as the information regarding why and how things should be performed might be inadequate.

Ignorance

Ignorance refers to the feature of the system and how the system is understood as well as how any individual/department understands what impact their decisions have on the system. For instance how their decisions impact changes the conditions for any other individual/department. As any flow, either tangible or intangible is forwarded though different actors in the flow, the knowledge of how ones actions affect the next party in the chain is vital.

The appearance of ignorance has been exemplified in the empirical data chapter where it has been mentioned that changes are good but people not always are aware of the consequences of the charges and how these can impact others. An example of this situation can be if one person wants to send a part to China, the part might be of low criticality and a delay in the customs due to improper specification might not have a significant effect to any project. However, as the part might be shipped in a same batch as critical material, lack of specification of one part in the batch might stop the whole batch in the customs. Other examples from interviews are decisions that are carried out in one department, but with consequences taken by another department, such as cost for transportation, increased lead-time due to more specifications etc.

Strategic objectives

Another problem between departments that operates together is that they might work towards different objectives. Examples of this can be one department that have cost as a main driver of its KPI's while another department have lead-time as the main driver of their KPI's (Key Performance Indicators). Examples of these are purchasing that work towards lowering cost, while R&D works towards reduced lead-time.

6.3 Possible improvement areas

The authors have searched through different literatures to find possible concepts for managing the complexity drivers described above. After studying the company, three different concepts were found to be relevant in terms of reducing the complexity in the test object process. These concepts are supply chain visibility, cross functional teams and front loading. In this section, these tree concepts will be discussed in more detail, first the concepts will be introduced from via a study of the literature regarding the concerned concepts. Secondly, the concepts will be discussed in the context of Volvo Car Group, and how they will be useful in reducing complexity in Volvo Car Group.

6.3.1 Supply chain visibility

The drivers of complexity represent the ability to evaluate the organization in terms of its capacity to supply the need for adequate information, as increased complexity drivers aggravate the transfer of good information. As have been demonstrated in the empirical data regarding e.g. purchasing and R&D which e.g. operates towards different objectives and where the complexity driver *strategic objectives* and *ignorance* is present as the departments has an obvious lack of understanding of each other's processes.

Besides evaluating the organization from the point of studying complexity drivers, another way of approaching the problem with supply and demand of information is to evaluate the supply chain in terms of its visibility. The purpose of this chapter is to address key factors related to complexity in order to achieve better conditions for operations efficiency.

Many authors agree that visibility and productivity is closely connected and where visibility provides benefits not only in terms of operations efficiency i.e. increased resource productivity, but also planning effectiveness (Caridi et al., 2010). The idea of supply chain visibility stems from the contingency theory (summarized by Mintzberg, 1979), which questions the traditional school of organization management. According to the traditional school of organization there exists a best practice when it comes to governing organizations and how they should be managed. According to the contingency theory however, an organization operates in dynamic environments where different conditions are created. By adapting to these conditions constitutes the most efficient way of managing the organization, which highlights the need for good information sharing, integration coordination etc. In this dynamic environment, an isolated model of leadership is not efficient; rather the style of leadership must be adapted to the situation.

In order to provide a base for information sharing, integration, coordination and defined information processing; structured development processes could provide necessary information by virtue of well-established step-sequenced process maps. However, strict step-sequenced processes and models for product development have received critics for being non-dynamic, rigid and presuming that relevant knowledge is available from start (Kihlander and Ritzén, 2012). In addition they also have a weak resemblance to practice according to Kihlander and Ritzén (2012). Although the weak resemblance to reality they still have a purpose according to the authors. Having common models which define the organization, this will facilitate establishment of rules, boundaries and procedures.

A consequence of lack of visibility can be poor management as relations in supply chain can be complex by nature and as a consequence, very dependent on the supply chain configuration. The supply chain configuration can further be analysed in terms of two context variables (Caridi et al., 2010) (see figure 27). The first context variable is the supply chain virtuality which for example mean to what extent one unit in the supply chain can rely on the supply chains ability to process flow of tangible or intangible resources as an organizational solution to a particular problem. Examples of low virtuality is the situation at R&D when persons responsible for projects have to spend time contacting purchasers in order to secure that the orders will be placed. Another example is material planners who may order more material than is initially specified as he might assume that some material is more inclined to be scrapped. A third example is when purchasers wait with placing orders as they know that some material is prone to change, and where the purchaser want to wait to the very last moment to collect all the changes in the purchase order.

The ability to rely on the supply chain ability is closely connected to the ability to be able to collaborate with partners in the supply chain. Essential to good collaboration is according to Caridi et al. (2010) to achieve good information sharing.

The second context variable is the supply chain complexity, which has been outlined previously. As management of increased information may be needed, the complexity in the supply chain could increase the time needed to process the information, or even bias the information. The need for visibility is related to the variability in the supply chain. The higher the variability is i.e. how often the context changes and at what velocity together with how fast the supply chain can correspond to these changing conditions is what creates the need for visibility. This statement is based on the assumption that when a problem occurs; the solution is information. Further if the information is available faster; the problem will be resolved faster. The supply chain visibility is therefore considered to be a response variable. The relation between context and response variables and performance is illustrated in figure 27 below.

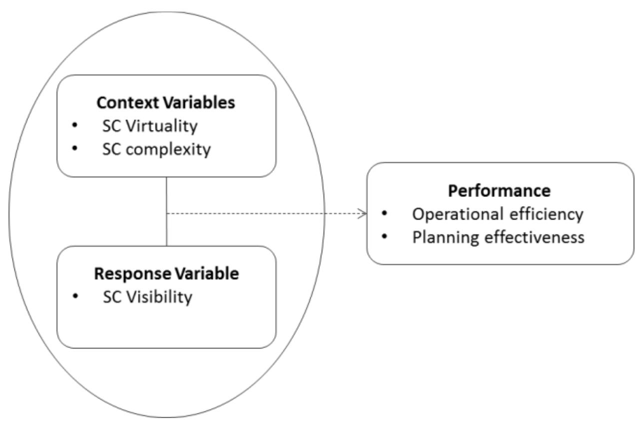

Figure 27 – Relation of supply chain context variables and response variables to performance (adopted from (Caridi et al., 2010)

The term visibility is not defined explicitly, but many authors focus their attention on the information exchange, defining visibility as "the ability to access/share information across the supply chain" and how the information is accurate, trusted, timely, useful and in a readily usable format (Caridi et al., 2010). The authors further conclude that any company qualitatively could evaluate their visibility and thereby gather useful hints in order to improve their visibility and operational efficiency. For instance, two units within an organization may have similar visibility in the supply chain, but one faces a lot of low-quality information, whereas, the other unit faces less, but high-quality information. For this reason, a company could evaluate how to improve the accuracy and freshness of the information; or the amount of information needed (Caridi, et al., 2010).

Achieving good visibility in the supply chain is related to the ability to achieve good information sharing. Good information sharing will have an impact on the ability to understand the organization i.e. the complexity driver *ignorance.* As visible information in the organization also might have an impact on the ability to avoid the need for looking around for information, supply chain visibility might also have a strong impact on the number of communication channels.

6.3.2 Cross-functional teams

The previous mentioned complexity drivers are results of actions taken on either individual or team level and created due to interpersonal relations. Due to the interpersonal influences, this calls for an investigation regarding how to work efficiently over functional boarders, i.e. cross-functional efficiency.

In order to establish cross-functional effectiveness, two dimensions of cross-functional teams have to be considered. The first dimension is the internal functional team which operates on an operational level i.e. tasks carried out by actors such as Test Object Manager (TOM), Test Object Leader (POB), purchaser etc. The second dimension relates to the activities that are carried out at management level and therefore serves as enabler for cross-functional activities to be established. The approach to work with internal cross-functional team and functional managers is outlined in figure 28 below and needed actions will be explained further on.

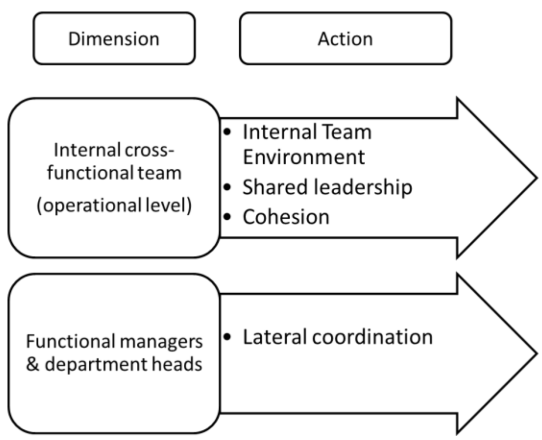

Figure 28 – Approaches of internal cross-functional teams, and functional managers

In order to create good condition for problem solving over internal functional boarders and supply chain visibility in a dynamic environment, the use of cross-functional team is a common practice. Cross-functional teams consist of individuals in various functions that work together in order to obtain a specific goal. Researchers find that diversity from different functions in the organization can have both a positive and negative influence over the cross-functional performance. Among the negative aspects highlighted regarding cross-functional teams are that the many areas of expertise, perspectives and knowledge can create knowledge barriers and conflicts across the functional boarders (Daspit et al., 2013). As a consequence, if the internal conditions do not support collaborative integrations, the members are unable to work collaboratively and the full potential of cross-functional teams is not fully utilized. Daspit et al. (2013) argue that the internal characteristics of the team will determine the effectiveness of the team. The authors analyses the characteristics of the team by using a framework of three internal elements. These elements are operationalized as *internal team environment* (stage setting element), *shared leadership* (enabling element) and *cohesion* (behavioral element). The relations between these elements are outlined in the figure 29 below.

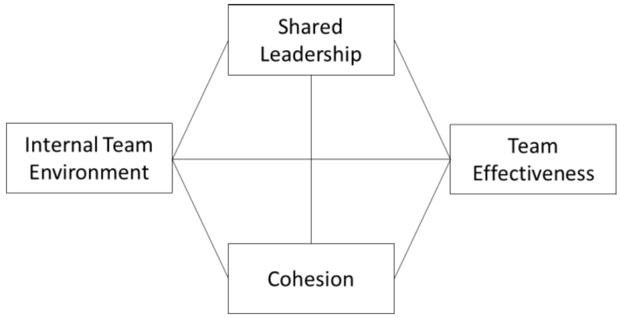

Figure 29 – Relations between internal characteristics of the team (adopted from Daspit et al. 2013)

Internal Team Environment and Shared Leadership: The nature of internal team environment consists of a shared purpose, which exists when team members have similar understandings of team goals and make an effort to remain aligned with the common objectives (Daspit et al., 2013). This is positively related to shared leadership, which means that the team have the ability to collaborate with each other at any given moment. Team leadership is in other word, not related to a single authoritative position. The authors also points out that the environment has a strong correlation to shared leadership. Related to the tenets of the social exchange theory, any individual who perceive strong support from their team will also experience an obligation to repay to the team.

Internal Team Environment and Cohesion: Daspit et al. (2013) defines cohesion as the tendency for a team to remain united in the pursuit of its objective. For instance if the team-members work in a group with interdependent tasks, the identification with the group in the part of team members will be reflected in a shared focus on task accomplishment (Daspit et al. 2013). In addition, teams that are able to exchange information, advice and share perspectives tend to be more cohesive. The perspective of internal team environment and cohesion relates to social identification theory which contends that interpersonal interactions create interdependent relationships among members.

Internal Team Environment and Team Effectiveness: Evaluating team effectiveness can be done by evaluating commitment, satisfaction, performance, environmental factors and numerous other factors. As mentioned previously, sharing of a common purpose is essential for good team effectiveness. In addition, other factors such as cooperation and communication are also vital for team effectiveness. This is also supported by the social exchange theory which explains that individuals who experience support from the organization are likely to feel compelled to help the organization or team to reach its goals.

Shared Leadership and Cohesion: Past research reveals that the traditional form of leadership contributes to cohesion to the extent that leaders engage in behaviours that increase members' attraction and desire to remain and interact in the team. The authors point out that when the traditional form of leadership is effectively used it can enhance the focus of the team and encourage information sharing among team members. The connection between shared leadership and cohesion has not received particular attention by researchers, however some studies reveal that teams engaged in shared leadership reported fewer conflicts and higher cohesion compared to teams that not shared leadership responsibilities.

Shared Leadership and Team Effectiveness: Team with members who have active participation in team tasks is a highly significant predictor of good outcomes together with lower conflicts and higher levels of satisfaction. In the context of shared leadership, individuals who engage in participative leadership roles may experience an obligation to continue performing at satisfactory levels, which influences the effectiveness of the team (Daspit et al. 2013). The authors also points out that shared leadership may serve as a mediating influence between the team environment and effectiveness of cross-functional teams.

Cohesion and Team Effectiveness: Cohesion provides a bonding force in teams and facilitates good group development. Positive team results due to cohesion often stems from high involvement, low friction between members, high level of trust, and great coordination.

Taken these aspects together, it can be concluded that organizations can be optimized by using the resources more efficiently. Team-members are more likely to participate in shared leadership roles, when they perceive a higher level of shared purpose. The team effectiveness is also enhanced when individuals engage in shared leadership, internal team environment and cohesion.

As demonstrated in figure 28 previously, vital for creating a base for good cross-functional collaboration is to involve department heads and functional managers and not only emphasize team members on an operational level. According to Anthony et al. (2014) better quality of coordination between department heads is associated with lower boundary conflicts as well as improved project efficiency.

Communication between department heads and functional managers does not contain specific information vital for the project; instead it contains information on a more aggregated level, denoted as lateral coordination. Lateral coordination is in other words above the cross-functional project team, and aims to increase the “fit” between the functional team and involved functional departments. Although, lateral coordination has a relationship to the cross-functional team to the amount of conflicts between the team and the department heads.

As cross-functional efforts draws resources from many departments or functions, team members often turn to their home department for resources and support. When department head engagement is not implemented, conflicts between department heads and the cross-functional team may occur (Anthony et al., 2014). Another aspect is the fact that the resources needed for the cross-functional project may be hard to garner as it may require authority by the department head to use and commit the resources to the project.

A third aspect is the fact that cross-functional teams may be challenged with implementing a cross-functional strategy which can create conflict across department boundaries. Lateral coordination will mitigate this problem by facilitating better involvement of all functions, and also assist department heads with better cross-functional understanding of the project and its task demands.

The authors together with several researchers also point out that early involvement of team members and upper managers for determining project goals, as well as monitoring and evaluating the project is positively associated with project performance. This is achieved as boundary-spanning conflicts and pressure to comply with conflicting expectations are likely to diminish. The relation between goal and project performance, by the presence of lateral coordination is outlined in figure 30 below.

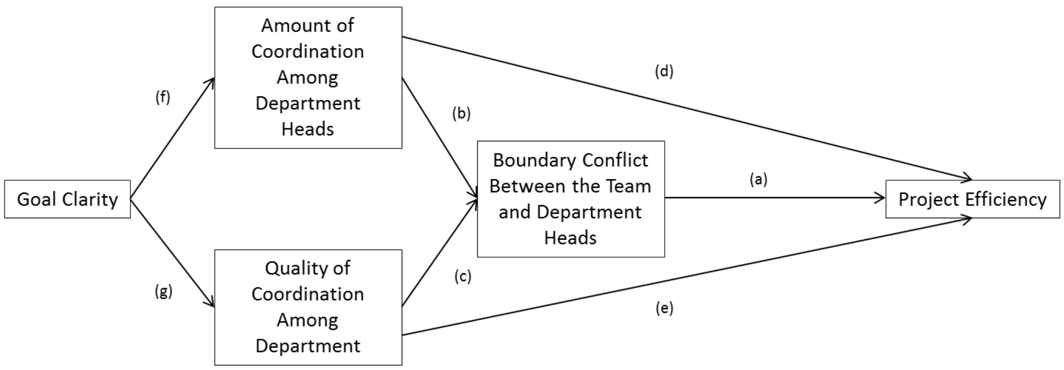

Figure 30 – Relation between goal clarity and project efficiency (adopted from Anthony et al. 2014)

(a) Boundary Conflicts and Project Efficiency: Anthony et al. (2014) conceptualize project efficiency in their research as the extent to which the cross-functional project team stays within their original costs and remains on schedule (although, project efficiency may have several more implications).

There are several reasons why boundary conflicts could hinder project efficiency. As team members seek information during external interactions, individuals from different functional backgrounds (both team members and functional heads) may have different thoughts and perspectives regarding the project. Functional department heads may not have the enriched cross-functional view of the project as the cross-functional project team does. This different view may lead to misunderstandings and conflicts between department heads and the project team impairing the project efficiency. The authors also refers to these types of misunderstandings as a route cause of job-related stress, lower job involvement, and commitment of the team members to the project, which will have a direct impact on the project efficiency.

Considering the assumption that different departments have different perspectives from team members or department heads who are more likely to view the project from their respective departments' perspectives. What can be done to reduce these differences?

This brings us to the links (b) and (c) in figure 30. As stated by Anthony et al. (2014), one way of enhancing the department head´s cross-functional view of the project is by facilitating cross-functional interactions. Cross-functional interaction and communication are critical for linking people and ideas, thus the amount and quality of the information will contribute to less boundary conflicts.

In addition to improved boundary conflicts as a result of increase qualitative and quantitative information sharing, it may also provide a direct effect on project efficiency. Research supports that projects become more efficient when coordination across functions is implemented (Anthony et al., 2014). As information and resources are shared across functions, decisions regarding project scheduling and budget are more easily coordinated, planned and facilitated. The bottom-line is therefore that more and higher quality of cross-functional coordination among departments is associated with more project efficiency.

(f) & (g) Goal Clarification: To the extent that managers can apply lateral coordination and successfully manage to cross project teams as mentioned above depends on the ability to form such organization. The authors concludes that it´s unclear what drives this lateral coordination. A possible driver is the clarity of goals established within the organization in the early stages of the project. Research has proven that early statement of goals promotes sustainable commitment of individuals and can also lead to more effective coordination and performance.

To explain how goal clarity can impact the performance of cross-functional activities the wider literature within the area of team goal setting is used. What this literature reveals is that goal clarity can help teams to communicate and perform better as clear goals will bring the team together and as the members knows their duties, responsibilities and what they have to deliver. The clarity of goals also facilitates communication among team members, and also more focused communication. On the contrary; when goal clarity is low, team members' individual actions has lack of focus and direction which can cause confusion and conflicts. The bottom-line regarding goal clarity is that great goal clarity at the early phase of a project is associated with more quantitative and qualitative will the cross-functional coordination.

Working with more collaboration over functional boarders requires approaches in two levels, first at the operational level but also at a managerial level by applying more lateral coordination. Lateral coordination aims to make functional managers and department heads to agree on common goals. This will therefore have a strong impact on the complexity driver *strategic objective.*

Working on an operational level the aim is to work towards better *internal team environment, shared leadership* and *cohesion,* the aim is to provide conditions for reducing variety/uncertainty as the team will support each other and work towards continuous improvements. This cross-functional work at an operational level will also reduce the complexity driver *number of communication channels* as finding the right communication will be facilitated. It will also have an impact on the driver *ignorance* as more process knowhow will be created due to better understanding of each other's processes. As more collaboration over functional boarders also may have an impact on the ability to discover problems and avoid rediscovery of old problems in new projects, the presence of cross-functional teams may also have a potential impact on variety/uncertainty.

6.3.3 Front-loading

In terms of the basic assumption that the lead-time for processes performance is strongly affected by the ability to solve problems and efficiently process information between the right parties; this calls for an examination of the link between operations management for product development and problem solving. Methods for improving cross-functional efficiency have already been addressed in the thesis and the purpose with this chapter is not to add a new dimension to the concept. Instead, it aims to point out a different way of working with strategies in order to elevate problems earlier in the process rather than just focus on improvements of information processing.

The link between project performance and superior product development has received greater attention the recent decades (Thomke and Fujimoto, 2000). Accordingly, much of the research within the area has focused on the dimension of product performance by the use of overlapping activities for increased speed of execution of projects. However, Thomke and Fujimoto (2000) highlights the importance of solving problems as early in the process as possible, as problems on average becomes more and more expensive and time consuming to correct as the project progresses. The authors point out that the emergence of computer-aided engineering (CAE) and rapid prototyping has accelerated problem solving in product development as problems has surfaced earlier in the process. Although these methods cannot apply for material flows between Europe and China, there still are lessons to be learned from this way of mind-set. By expanding this principle and apply it to a management perspective; the ambition is to concentrate the efforts how to move (or "load") the problem identification backward in time to the beginning (or "front") in the process of forwarding information between actors.

As pointed out; the concept of front-loading builds on the strategy for identification of problems to earlier phases in the product development process but the mind-set could still be valid for the thesis scope. Thomke and Fujimoto (2000) points out two particular strategies for achieving effective front-loading.

The first approach is to apply *rapid problem-solving*, leveraging advanced technologies and methods to increase the overall rate to which problems are identified and solved. Examples of these methods can be, rapid prototype printing for verification or virtual verification by using computer-aided engineering (CAE). However, *rapid problem-solving* is considered to be out of the scope for the thesis and were only brought up to show the first approach by Thomke and Fujimoto (2000).

The second approach, which is more applicable, and the mind-set Volvo should consider, is *project-to-project knowledge transfer* with the aim of efficient transferring of knowledge between projects in order to reduce the number of problems to the onset of activities. This approach relates to the ability of processing information and to solve a problem, problem- and solution related information must be available and recognized by the problem solver. The information can be available in two ways (Thomke and Fujimoto, 2000);

(1) It already exists as very similar problems were identified and solved in prior projects.
(2) It is created as a part of repeated problem-solving during the process.

With regard to information that already exist, the author points out that a process must be in place in order to bridge the gap between the need for information and the source of information. In addition, firms often neglect the project-to-project learning and information transfer, resulting in "rediscovery" of old problems in new projects (Thomke and Fujimoto, 2000). With regard to information that is created as part of repeated problem solving during the process, this refers to the point in time in the process when the "problem-solution" actions are started.

Another reason for lack of information sharing is the complexity in large projects where people may be unaware of the chain cause and effect of a particular action, which also has been outlined in the empirical data. Resulting in disinclination to seek or provide necessary information. Related to unavailability of information is the fact that information may be created as a part of the problem solving process and therefore created late in the process. An approach to solve this problem is to shift decisions to earlier stages in the project. However, practice often looks different: resources are ramped up slowly as the project unfolds, and thus are the problem – solving activities and the related generation of information slowly ramped up as well (Thomke and Fujimoto, 2000). Hence, the identification of problems are shifted downstream ("end-loaded").

The aim with front-loading is twofold: (1) improve project-to-project knowledge and (2) elevate improvements to earlier stages in the process. Improved project-to-project knowledge will have an impact on complexity as it will have a direct effect on the drivers' *number of communication channels* and *ignorance* due to the fact the process knowhow and communication between departments will be facilitated. As the team also operates towards a joint goal it will also have an impact on *strategic objectives.* By elevating problems to earlier stages in the process, this will move the *variety* and *uncertainty* away from critical points in the process, e.g. close to point of dispatch of material.

6.4 Discussion of organizational view

In order to reduce complexity and ultimately lead-time, it is needed to discover and solve problems earlier in process. As have been pointed out by some departments at Volvo; namely that the information sharing is of more personal nature than on joint information sharing nature, although all departments are involved in the fulfilling of the processes. This calls for a shift of work procedure to include more learning in processes with more project-to-project knowledge and increased cross-functional collaboration. Another gain with earlier problem solving (or "Front-Loading") is that fewer problems will remain unsolved closer to critical timings, e.g. when the material has to be ready for dispatch. The reason for this is that problem solving activities affects the conditions and the ability to plan and coordinate, and hence static and good planning conditions is something that is desired close to goods dispatch, this demonstrates the importance of having problems solved as early in the process as possible.

The importance of project-to-project knowledge and cross-functional collaboration is demonstrated in the figures below, which represents the aspects of front-loading and supply chain visibility taken together. Figure 31 is based on the assumption that the solutions to internal problems is the availability of information, and that the information either can be gained by knowledge within the particular domain or visible information. Figure 31 illustrates recognition of a proportion of problems P_1 recognized at the time T_1 in a process. The problem is solved with a constant rate r_{12} at the time ΔT.

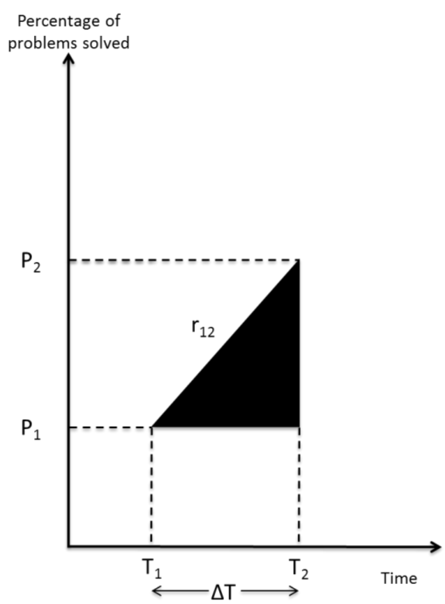

Figure 31 – Conceptual model of traditional problem solving rate

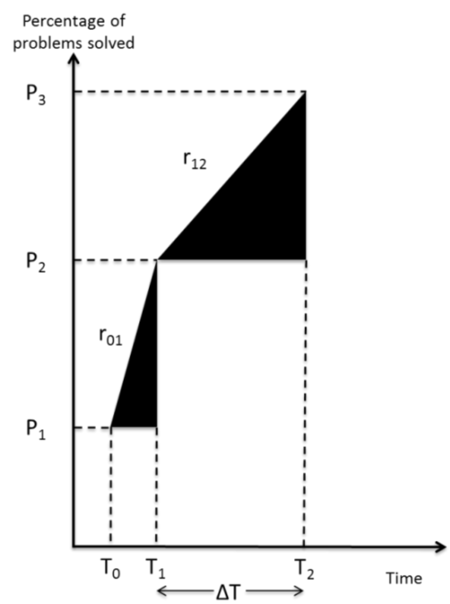

Figure 32 – Conceptual model of traditional problem solving rate with front loading

Considering efficient project-to-project knowledge transfer where project knowledge and information is gained by either:

1. A similar problem has been identified and solved in prior product development processes
2. Information is created as a part of repeated problem-solving during the development process
3. Visibility of related information

The result is earlier recognition of problems and faster problem solving. This is illustrated in the conceptual model in figure 32 above. Considering a problem recognized earlier at time T_0 due to better functional collaboration and increased visibility, the problem is also able to be resolved at a faster rate r_{12} due to improved operational performance, identification of similar problems parallel to, or previously to the actual project. The result is a higher proportion of problems P_3 resolved at the same time T_2.

Two important dimensions needs to be considered from a cross functional team perspective. The first dimension relates to the fundamental role of frontloading which is to provide better collaboration and learning on an operational level, here the dimensions *Internal Team Environment, Shared Leadership* and *Cohesion* must be considered.

The second dimension relates to the management perspective regarding how the cross-functional teams are governed. As managers' state goals for their departments, different departments must have similar goals in to work properly jointly with other departments on an operational level. Vital for operation efficiency in frontloading is to clarify goals in order to monitor and follow up performance. By following clearly defined goals in cross-functional teams and doing constant follow ups in order to target improvement areas to coming projects; this may have a significant impact on the ability to lower the complexity driver *ignorance* as this driver comprises the ability to understand the system and what impact your decisions have on it.

In order to set joint goals for the cross-functional team, goals and responsibilities for every contributing department have to be clearly defined. As described in the empirical data, departments are not always aware of how their decisions impact other departments. Further it is also implied that departments tend to shift the responsibility for consequences to other department, e.g. claiming that the previous department should deliver a certain output in order for the next department to do their job. This example is illustrated in figure 33 below, if the responsibility of department A ends after department B is taking over the responsibility at point (i) without clarification of output/input between the departments. This may stir up a catch 22 as a grey-zone exists regarding what department that have the responsibility for what, resulting in a situation when departments blame each other for any cause of disturbance in the process. The solution is therefore to agree and clearly state the input and output between the department that has a functional collaboration and only focus on their own performance.

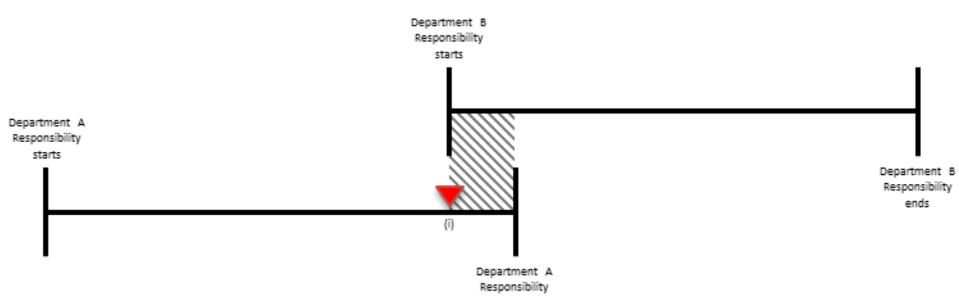

Figure 33 – Grey zone of responsibilities between departments

In order to design operations and decide responsibilities, the model for project efficiency mentioned above (see figure 30), can serve as a base for decision and a guide for possible improvements. Considering for instance, operations regarding process of material flow, which either should be carried out at Maastricht or at R&D in Torslanda, which also has been discussed in chapter 5, another way of evaluating this decision is to evaluate it in terms of operational efficiency. As documentation for Chinese customs is a sensitive part in the material flow and a potential driver of lead-time if the documentation not is done according to the right standards; it is therefore a process that requires project efficiency. As discussions has arisen at R&D regarding which department that should carry out the documentation and no solution has been made, there might exist an underlying boundary conflicts that must be resolved in order to set prerequisites for good project efficiency. Another aspect that has been mentioned is the deficient information channels, both in terms of amount and quality of information. What should be evaluated is how this information can be provided such as access to information systems, changed output from previous departments etc.

The last aspect is the goals, which must be aligned in order to create commitment to work in a joint direction. Examples of shared goals can be if operations for R&D carried out at Maastricht are affecting the KPI of Maastricht.

This discussion about the organizational view has outlined three actions to consider in order to create better collaboration over functional boarders and how these actions relates to the drivers of complexity. The relation between the improvement areas and their relation to complexity drivers are mentioned in the end of the sub-chapters, where each action is described. A summary of the relations between complexity drivers and mentioned improvement areas is illustrated in table 8 below.

Table 9 – Relation between improvement areas and complexity drivers

Improvement Area / Complexity Driver	Cross-Functional Team Efficiency		Supply Chain Visibility	Front-Loading
	Operational	Managerial		
Variety/Uncertainty	(Strong)			Strong
Communication Channels	Strong		Medium	Strong
Ignorance	Strong		Strong	Strong
Strategic Objectives		Strong		Strong

If an improvement area had a potential effect on the complexity driver, then the relation is pointed out with stating “strong” or “medium”, which resembles the strength of the potential. The connection between *variety/uncertainty* and operational cross-functional team efficiency is presented in brackets, because the relation can be considered indirect.

Table 8 takes together the findings from the chapter six, which was aimed to present an organizational view on the process of getting materials from Europe to China to identify risks of increased lead-time, and highlight improvement areas for lead-time reduction. Complexity drivers can be potential risks and the actions described as the improvement areas can be used in order to target any driver of lead-time or potential for decreased delivery precision. By identifying critical paths in any flow, this can be analysed in terms of e.g. table 8. For instance, if a particular flow has interactions between R&D and purchasing as a critical part of the process, this can be targeted by applying more lateral coordination on management level. Another example is processes involving e.g. the department of Design & Development and Test Object Department. If it is found that operations not are done efficiently and this is found to be a result of lack of process knowhow (*ignorance*), the solution could be to provide an access point between departments providing more collaboration, front-loading etc.

7 COMBINING THE PROCESS AND ORGANIZATIONAL VIEW

This chapter will bring together the key findings from the process view and from the organizational view of getting materials from Europe to China, and provide a joint discussion over the risks of increased lead-time and improvement areas for reduction of lead-time. Firstly, the identified risks and improvement areas will be brought up again followed by a discussion about them.

In previous two chapters, the process approach and organizational approach have been described. These approaches have taken a different viewpoint on to the same research object; process of getting materials from Europe to China. The aim of both approaches was to identify risks of increased lead-time and highlight improvement areas for reduction of lead-time. Since the approaches were different, the findings from both parts are somewhat different. But, since the research object was the same, some findings might be still very similar. Nevertheless, these two approaches will provide a more comprehensive picture of the desired outcomes. Both views have to be taken under consideration and discussion, so a joint view could be presented and this is the aim of this chapter.

7.1 Risks of increased lead-time

Firstly, the identified risks of increased lead-time will be brought up. The authors were able to identify several risks using process mapping and process analysis. The identified risks were divided into four risk areas; knowledge risks, work process risks, transfer pricing risks and system constraints risks. The identified risks under each risk group were:

- **Knowledge risks**
    - Knowledge about documentations
    - Knowledge about customs regulations
    - Knowledge about packaging

- **Work process risks**
    - Insufficient information quality
    - Unclear responsibilities between actors
    - Shipment documentations not ready
    - Parts not available at internal storages
    - Complete car order not ready in factory system
    - Inter-Company Order (ICO) not released before shipment

- **Transfer pricing risks**
    - Difficult to set the transfer price
    - Incorrect transfer price

- **IT systems risks**
    - Purchase order not placed due to purchasing system setup
    - Losing information about parts due to different information system setup

Longer elaboration about each risk can be found above in chapter 5.4.4. The concept of complexity was used to provide the organizational view on the process. Four complexity drivers were used as a baseline to identify the risks of increased lead-time in the company. According to these four complexity drivers of variety/uncertainty, number of communication channels, ignorance, and strategic objectives, the following risks of increased lead-time were identified:

- **Variety/uncertainty**
    - No predetermined supplier
    - No standardized flow

- **Number of communication channels**
    - Ambiguous responsibilities

- **Ignorance**
    - Lack of knowledge

- **Strategic Objectives**
    - Measuring on different KPI's

The motivation is that these complexity drivers complexity level in the organization and complexity will drag down the efficiency of the process, therefore, eventually risks of increased overall lead-time.

7.2 Improvement areas for lead-time reduction

Next to identifying risks, the second purpose was also to highlight improvement areas for lead-time reduction. From the process view, specific improvement areas were highlighted, which were found, when examining the mapped processes. These improvement areas were presented in three process parts; from analysis and verification need to specification, from specification to material delivery in the process of Pre-Buy-Off (PBO), and from specification to material delivery in the process of Machine-Try-Out (MTO) and Verification Prototype (VP). The key improvement areas mentioned will be taken together below.

The first improvement areas were found in the process from *Analysis and Verification need to Specification*, which encompassed:

- Deletion of non-value adding activities
- Educate actors on how to fill in correct and adequate information from the beginning, e.g. the AVB-list, or how the Quality Leader (QLT) could fill in the Test IDs himself.

These improvements could be questioned how much lead-time they would actually save in the total process, but it was discussed that the improvement could set a required foundation for; further improvement and a higher quality for preceding activities and actors.

The second improvement area that was discussed was from *specification to material delivery in the process of Pre-Buy-Off (PBO)*, and contained:

- A standardisation of material flow suggestion was stated that Maastricht Knock-Down facility should be responsible for managing the material flow process. Mainly because their superior knowledge about documentation and packaging, and the point of letting the pilot plant and R&D department handle their core business.

The improvement would set the foundation for a standardized flow, which is an enabler for measurability and further, control of the process. This, in turn, is a prerequisite for continuous improvement, and better quality in the process.

The third improvement area was from *specification to material delivery in the process of Machine-Try-Out (MTO) and Verification Prototype (VP)*, and included:

- Work organization and work culture
    - Make sure that actors understand their tasks, and how their decisions would affect subsequent actors and activities.
    - Respect for deadlines.
    - Visibility of information and how communication is done.
    - IT-system could be improved, but it is assumed to be a too costly investment to overweight the reduction in lead-time.

A consideration of these improvement areas could lead to a faster and more precise process.

The organizational view from chapter 6 provided three improvement areas to deal with the complexity drivers, and thus the risks. The first presented improvement area was:

- Supply Chain Visibility

With improved Supply Chain Visibility, more and better information sharing could be gained. The second improvement area was:

- Cross functional team efficiency

As discussed in chapter 6, positive effect from having good cross functional team efficiency could be; first, improved collaboration between departments on operational and managerial level. Second, Coordination and integration of activities could be facilitated.

The third area of improvement from the organizational view was the concept of:

- Front-Loading

The mentality of early problem detection, and knowledge transfer from project-to-project could be highly beneficial in terms of reduction of lead-time in the test object process.

7.3 Discussion

All of the identified risks and improvement areas outlined above are important to consider for Volvo Cars. This section aims to provide a general discussion about those risks and improvement areas to provide a joint view and highlight key themes that were found by the authors.

When looking at the risks of increased lead-time from both, process and organizational approach, it can be seen that there exist some overlapping risks identified. One conclusion to be made is that these risks are important to target, since they affect both the actual process, and the surrounding organization. One example of risks that were found both from the process view, and the organizational view is the knowledge risks. As it was drawn out from the process view, then risks regarding lack of knowledge in documentations, customs and packaging could lead to increased lead-time. Similarly, the organizational view identified lack of knowledge as a driver of complexity and therefore lead-time. Second example of risks that strongly correlate to both approaches is the work process risks from process perspective, and the risk of having ambiguous responsibilities from the organizational view. They both indicate to issues that either, the work processes are not clearly defined, or the actors do not follow the determined processes, thus creating risks of increased lead-time for downstream actors and activities. These risk groups have a strong connection to each other and they have to be considered a risk that should be dealt with to reduce lead-time.

Usually, in big companies, such as Volvo Car Group, different processes are defined. In terms of Volvo Car Group, the processes are mapped down and stored in Volvo Business Management System (BMS). Though, this does not mean that the work or the work processes are standardised and followed. When studying the process of getting materials from Europe to China within the established scope and assumptions, the authors have seen that there is still ambiguity and lack of clearly defined work processes. Therefore, in different occasions the process could go either one way or another and there are no clear rules regarding which way the material has to go. Obviously, this would mean that it is very hard to measure the total lead-time in exact days in the current situation. If it is not possible to measure the situation, it is not possible to control it, and moreover, not possible to improve it.

The lack of standardisation has led to one clear improvement area that was highlighted from both perspectives. There still exists a demand to firstly, deeply understand the activities, tasks and roles of actors, thereafter, cut out activities that are not adding value as well as rearrange activities so they are done at the time when needed and lastly, standardise the flow according to the best found way. The authors have made some suggestions what should be considered regarding cutting out and moving activities, but further examination of the activities could reveal even more potential changes. Also, the suggestion to standardise the management of material flow by giving the responsibility to Maastricht facility should be considered. This activity, as explained, would also simplify and normalize the physical flow of material by reducing optional flow paths.

The standardisations should not only include work processes, but also define the roles and more specifically the outputs when, how and in which detail the actors should provide. Example would be clearly defined what information and how should the information in documents be forwarded. As the organizational view stated, then cross functional teams is a potential measure to reduce the complexity in the system. Standardized work processes, roles and clear outputs would help to make these teams work together more efficiently. One way to understand it is that cross functional team meetings should be as well standardised. Clearly stated who should be present, what the roles are, what the goal is and what output should come from the meeting.

After a critical deep examination of the process is done and changes have been made to create a smooth and clear standardized process, a desired decrease of lead-time or increase in efficiency might still not be seen. The reason is that merely stating the standardisation is not enough; something has to be done to help and motivate actors to follow the standards and rules. As it was identified, then one big risk area found was lack of knowledge, which also encompassed the lack of understanding of the needed quality of outputs. There is no use of standards, when actors do not understand them and hence, do not act according to them. Therefore, a second important improvement area that can be highlighted is education. This improvement area, as seen from both process and organizational view, has many facets, which will be discussed below.

Firstly, to relate the improvement area straight to standardisation, then education has to be done in terms of process, roles and documentation. It is important, that actors have at least some level of understanding of the full process, not only their own activity. They should know how their actions or miss-actions are affecting the process and why they have to produce certain outputs with certain quality level i.e. know their work importance. Additionally, subsequent actors should clearly understand the interfaces and roles that are set in place. Thirdly, when documents and information sharing is standardised, actors need to be educated to make it sure that they know how to produce these documents. Education should be also done to mitigate the knowledge risks described above, such as customs regulations. Packaging knowledge risk could be possibly reduced by moving the responsibility of managing the packaging activities to the facility, which possesses these skills and knowledge.

After being sure that the actors truly understand the set standards and they know what, how, in which way and why they have to do certain activities, then benefits can be expected. The outcome from working with the improvement areas discussed above is eventually reduced lead-time. Some improvements, such as cutting waste activities, will have a direct impact on lead-time. But mostly, the improvements will create a smooth and working process, which will have an indirect impact on reduction of lead-time. The smooth process is the foundation for further lead-time reduction. Moreover, discussed improvement areas will increase the quality of activities and outputs from activities. Having less errors has a straight link to lead-time reduction, since extra work is not needed in later activities.

In summary, the authors conclude that standardisation of processes, work, roles and documentations combined with the right education regarding the standardisations and other knowledge areas, will have a positive impact on lead-time reduction. Though, all of the risks of increased lead-time and highlighted improvement areas presented are important to take under consideration.

8 CONCLUSIONS

The first purpose of the thesis spawned from the detection that, the build logic for the Verification Prototype (VP) in China was not fully developed. The European build logic was used in planning purposes, without full understanding of the difference in duration of activities in China compared with Europe. That could be seen when comparing plans for Europe and the created plan for Europe, potentially resulting in wrongly set Material Requirement Dates, which would delay the delivery of the Verification Prototype (VP) build, thus poor delivery precision is a big risk. The authors have created a new build logic for China which contains; the needed activities, the duration of activities, and in which order the activities should be carried out. The build logic is presented in the form of a plan that Volvo calls, Integrated Activity plan (IA-plan). If the build logic for China, created by the authors is used, this sets a better foundation to derive the correct Material Requirement Dates (MRDs) which, in turn, is a prerequisite for good delivery precision. Thus the created build logic is a suggestion for improvement in delivery precision for the Verification Prototype build in China, and the first purpose of the thesis was fulfilled.

The result relating to the first purpose was the correct Material Requirement Dates (MRDs), which were then used as an input for the second purpose of the thesis work, namely to ensure that the process of getting materials from Europe to China, to meet those Material Requirement Dates on time and in the right quality. There were three process taken into account when considering the material need from Europe to China; the Pre-Buy-Off process (PBO), Machine-Try-Out (MTO) process, and Verification Prototype (VP) process. The three process had different material needs but similarities in the process of getting materials for, the Machine-Try-Out (MTO) and Verification Prototype (VP) made the authors treat them in one process map, whilst the Pre-Buy-Off (PBO) process were treated separately. Identification of risks of increased lead-time in all processes mentioned, from the process view and organizational view were made. Additionally, several improvement areas for decreased lead-time were found in the processes, both from the process view and organizational view. Thus, the second purpose of the thesis could be stated as achieved.

8.1 Future studies

The thesis has indeed set a foundation for further improvements in the test object process, however, the limitation of only considering production parts available in Europe, set some boundaries for the project work that been very helpful in clearing out complex situation, and eliminated a lot of variety in the process. If this scope should be expanded to also include not yet fully developed parts, i.e. pre-series parts, some interesting and definitely challenging future investigations could be made by Volvo themselves or another thesis project. The authors outline a few of these endeavors below.

Firstly, the authors believes it would be interesting to see where the major risks of increased lead-time and improvement areas for decreased lead-time, would be when taken the pre-series part into account, and the conducted thesis work could be a baseline to start from. Further, the aspect of complexity reduction, could then be examined from and earlier stages of product development to e.g. SOP (Start of production).

In addition, the work to target the mentioned complexity drivers has emphasized the use of cross-functional work, except the endeavors to facilitate supply chain visibility. The drawback of using cross-functional teams in order to create process knowhow and improved information channels is that it only target persons working over functional boarders. This may exclude persons not working over functional boarders or for any reason not can be a part of cross-functional teams. In order to cope with this situation, future research should also investigate how learning/education can be provided in order to create good conditions for creation of better process knowhow in the whole organization.

As the thesis has emphasized the use of cross-functional teams, no effort has been given how to implement such actions. Creation of a learning organization by the use of cross-functional teams is in itself a lead-time driver. Although there is a strong potential for good results in terms of lead-time reduction by using cross-functional teams, the importance of proper management for implementation, and where in the process to put the access point for the cross functional teams cannot be emphasized enough. In addition, implementation strategies for other suggested improvement areas could be an interesting aspect to look into.

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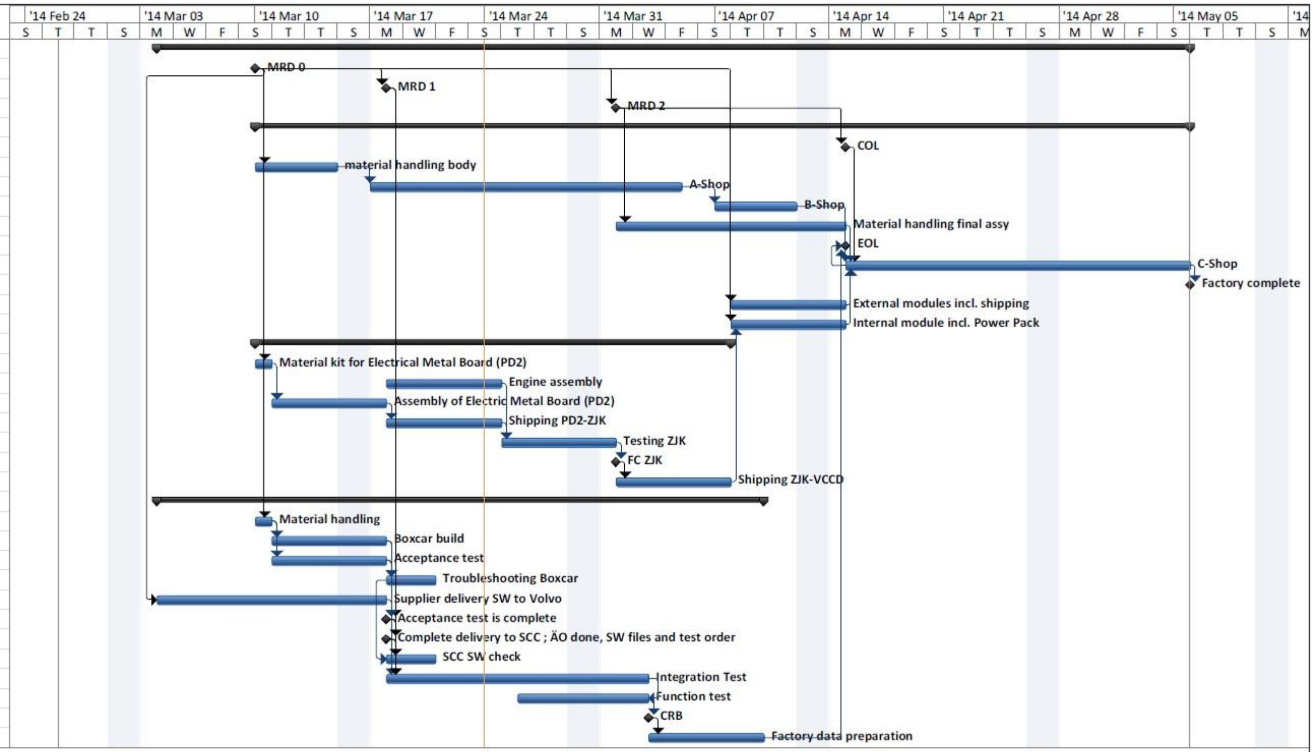
10 APPENDICES

Appendix 1 – IA-plan template for China

ID	Name	Duration
1	**IA- Plan China**	**45 days**
2	MRD 0	0 days
3	MRD 1	0 days
4	MRD 2	0 days
5	**Chengu (VCCD)**	**41 days**
6	COL	0 days
7	material handling body	5 days
8	A-Shop	15 days
9	B-Shop	5 days
10	Material handling final assy	10 days
11	EOL	0 days
12	C-Shop	15 days
13	Factory complete	0 days
14	External modules incl. shipping	5 days
15	Internal module incl. Power Pack	5 days
16	**Zhangjiakou (ZJK)**	**21 days**
17	Material kit for Electrical Metal Board (PD2)	1 day
18	Engine assembly	5 days
19	Assembly of Electric Metal Board (PD2)	5 days
20	Shipping PD2-ZJK	5 days
21	Testing ZJK	5 days
22	FC ZJK	0 days
23	Shipping ZJK-VCCD	5 days
24	**Shanghai (PD2)**	**27 days**
25	Material handling	1 day
26	Boxcar build	5 days
27	Acceptance test	5 days
28	Troubleshooting Boxcar	3 days
29	Supplier delivery SW to Volvo	10 days
30	Acceptance test is complete	0 days
31	Complete delivery to SCC ; ÄO done, SW files a	0 days
32	SCC SW check	3 days
33	Integration Test	12 days
34	Function test	6 days
35	CRB	0 days
36	Factory data preparation	5 days



Project: IA-plan for China
Date: Mon 14-03-24

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Page 1

Appendix 2 – Chinese IA-plan activities and milestones

Integrated Activity (IA) Plan for China			
Task	**Activity/ Milestone**	**Description**	**Goal**
MRD 0	Milestone	Material Required Date. The first time materials are needed for the build of the test series (Components for body, boxcar and powertrain rig). A crucial timing to which many different activities and processes needs to be adapted.	Making sure different activities and processes are coordinated so that builds can start when they are supposed to.
MRD 1	Milestone	Timing when the Boxcar build needs to be finished and SW[1] delivered from suppliers.	Making sure timings are met in order to have the test object built in time.
MRD 2	Milestone	Timing when materials are needed for the final assembly.	Ensuring material needs for the final assembly.
Chengdu Production Plant (VCCD)			
Task	**Activity/ Milestone**	**Description**	**Goal**
COL[2]	Milestone	The point of time when the specification in BOM is frozen and the body is called off to the assembly.	
Material Handling (Body)	Activity	Handling of ingoing material to the car body.	Ensure that materials that are needed to build the car body are ready.
Equipment Control	Activity	Check of fixtures and rigs holding the body not to be in the way of welding and other operations.	Making sure that welds and other operations can be carried out in the assembly.
A-shop	Activity	The body assembly.	A complete body to be sent to painting.
B-shop	Activity	Painting activity.	A complete painted body.
Material Handling (Final Assembly)	Activity	Handling of ingoing material to the final assembly.	Ensure that materials that are needed in the final assembly are ready.
C-shop	Activity	Final assembly and verification.	Complete test object which are used for verifying test objectives.

Internal Modules incl. power pack	Activity	Modules that are built in-house for the final assembly.	All modules needed to build the test object.
EOL[3]	Milestone	The SW is downloaded into the test object.	Test object with complete and correct SW.
Factory Complete	Milestone	A status the test object gets, saying it is complete and can be deleted from the plans.	
External Modules incl. shipping	Activity	External modules, e.g. seats are made and shipped to Chengdu.	Complete modules to be used in the final assembly.
Zhangjiakou Engine Plant (ZJK)			
Task	**Activity/ Milestone**	**Description**	**Goal**
Material kit for Electrical Metal Board (PD2)	Activity	Specify the material kit for the electrical metal board in Shanghai.	**??**
Engine Assembly	Activity	Assemble of engine.	Complete functioning engine for testing.
Assembly of Electrical Metal Board (PD2)	Activity	Electrical metal board being assembled in the pilot plant in Shanghai for Zhangjiakou.	**??**
Shipping PD2 - ZJK	Activity	Shipment of the electrical metal board to Zhangjiakou.	Deliver electrical metal board to Zhangjiakou.
Testing	Activity	Test of engine in Zhangjiakou.	Making sure that the engine works according to specification.
Factory Complete, Engine	Milestone	A status meaning that the engine is complete and can be delivered to the production plant in Chengdu.	
Shipping ZJK - VCCD	Activity	Shipment of engine from Zhangjiakou to the production plant in Chengdu.	Engine delivered to Chengdu for the final assembly.
Shanghai Pilot Plant (PD2)			
Task	**Activity/ Milestone**	**Description**	**Goal**
Material Handling	Activity	Handling of material for the Boxcar Build.	Ensure that materials that are needed to build the Boxcar are ready.
Boxcar Build	Activity	The physical build of the Boxcar.	A complete Boxcar to be used to various testing.
Acceptance Test	Activity	Testing of individual components.	Making sure that each individual component work

			as intended.
Troubleshooting Boxcar	Activity	After build additional troubleshooting can be necessary if something does not work.	Making sure the Boxcar works as it is intended.
Supplier Deliver SW to Volvo	Activity	Delivery of SW from suppliers.	Ensure SW is ready for the later testing.
Complete Delivery to SCC[4] ; CO[5] done, SW files and test order	Milestone	A point in time where certain activities need to be ready to be sent to SCC.	SW Files and specifications ready in order for SCC to do their job.
SCC SW Check	Activity	SCC checks that delivered SW is able to communicate with Volvo systems.	Making sure that SW can be used in the Volvo system for the test object and archive.
Integration Test	Activity	Checking if the SW works together with each other and with the HW[6].	Release of SW to factory systems and ensuring that the car can be put together in a good way.
Function Test	Activity	Testing the Boxcars functions.	Ensuring functionality according to specification.
CRB[7]	Milestone	Formal release of SW to factory systems and after sales.	
Factory Data Preparation	Activity	The build plant download SW	Complete SW to the test object in the build plant.

[1]SW = SoftWare
[2]COL = Car On-Lne
[3]EOL = End Of-Line – programming
[4]SCC = Software Configuration Centre
[5]CO = Change Orders
[6]HW = HardWare
[7]CRB = Configuration Release Board

Appendix 3 – AVB total list information cells and responsible actors

	AVB total list information cells	
	Information row	**Reponsible actor**
1	ID	QLT
2	AVB-status	QLT
3	Ordering team	Orderer
4	Resp for Order Name	Orderer
5	Resp for Order phone no	Orderer
6	Geo/office	Orderer
7	Resp for Order CDSID	Orderer
8	Build Series	Orderer
9	AVB Type	Orderer
10	Test description	Orderer
11	Part description (all material needed, main part and surroundings)	Orderer
12	Surounding parts	Orderer
13	Product no-12 +option	Orderer
14	Quantity	Orderer
15	Test area/Plant	Orderer
16	Start date of test XXwXXdX	Orderer
17	End date of test	Orderer
18	Material delivery date MRD	QLT
19	Hours	Orderer
20	Destructive test?	Orderer
21	Cost Typ	QLT
22	Cost	QLT
23	Recievername	Orderer
24	Recieverphone no	Orderer
25	Delivery address	Orderer
26	Notes, if applicable	QLT or Orderer
27	Test ID	QLT
28	Sourundings (Test ID)	Orderer
29	Lab95-ID	QLT
30	PO-needs	?
31	Factory	?

Appendix 4 – Order sheet

MATERIAL ORDER - SERIES					
Date:		C-mtrl ID:KDP		Int. code:	
Issue:		C-mtrl ID:POS		Ext. code:	
Project:		A-mtrl ID:		KU no:	
Series:		Product no:			
Desired delivery week:		Prio no:			
Option:					

Requester:			
Requester:		Phone:	
Name 2 :		Phone:	
Dept:		Plac.:	

Delivery address: Receiver	Dispatch order
Delivery address: *Indicate test no. on deliveries*	

Tests to perform (according to lab 95)

Requisition number	Test name/heading

FREE TEXT:

C/A material (Delivery module shall be marked with LMOD)

				Assembly						Undercoating									
				Assembly. in A-Shop:	Assembly in B-Shop/painting:	Assembly in C-Shop/HOP :	Assembly in VCCPP	BIW rework end modification		A-shop adhesives/sealings	ED-coated	Paint	NVH	EP2009 PVC	DC431	SB140, SSD	CI5	ML	
Part no.	Description	Quantity:	Fastener	YES	YES	YES	YES	YES		YES	YES	YES	YES	YES	YES	YES	YES	YES	

Appendix 5 – Shipping documentation needs

- **Invoices** - 2 original signed commercial invoices in English

- **Pro-forma invoice** - The pro-forma invoice is not an invoice as such, but rather a customs clearance document. The pro-forma invoice must contain the following information:
    - Order number
    - Part number
    - Part name (English and Chinese)
    - Function, Material, Instruction, Principle of work and Brands
    - Origin
    - Quantity
    - Price per unit and total amount
    - HS code
    - Customer details
    - Delivery term
- **Packing list** - Packing list in English with exact description of the goods, number of packages and dimensions

- **Dispatch order**
    - Explanatory text
    - Receiver details (name, address, etc.)
    - Issuer
    - Date and time of issue
    - Transport mode
    - Part details (weight, size, part no.,quantity, origin, price, etc.)

- **Delivery note**

- **EAD – Export Declaration Document**

The export declaration document is a mandatory document which must be added to the other papers which you send. When your goods enter or depart from the EU, a customs declaration must be performed. This is applicable for import, export, transit of temporary import.