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Performance During Manufacturing Start-up

- A Case Study in the Chinese Automotive Industry

Master's thesis in the master's programme Production Engineering

PÄR ELIASSON

Department of Technology Management and Economics
Division of Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
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Pär Eliasson

Supervisors:

Assoc. Prof. Peter Almström, Chalmers University of Technology

Thomas Broman, Platform Director Volvo Business Unit, Johnson Controls Inc.

Department of Technology Management and Economics
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PÄR ELIASSON

Report No. E2015:107
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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PÄR ELIASSON
Department of Technology Management and Economics
Chalmers University of Technology

ABSTRACT

The purpose of this master thesis is to analyze Johnson Controls Inc. (JCI) operations on their seating production and connect this with previous research to evaluate their start-up performance and if there are still disturbances from the start-up phase in the system. How these disturbances take action, what could have been done to avoid them and also how to improve operations. Previous research on performance during manufacturing start-up has mostly covered the electronics-, automotive-, and machine intensive industry. This study aims to add to the research by conducting a case study at a first tier supplier for the automotive industry.

The project used a case study method including both qualitative and quantitative data collection. Data was collected at JCI's plant in Chengdu, China during 5 months in 2015. To analyze JCI's operations today, value stream mapping was used. With this analysis, some improvements were implemented or proposed to JCI.

JCI's start-up performance showed to follow a learning curve with regards to capacity and quality. These results showed to be consistent with those of previous research. The analysis of JCI performance showed that some of the problems could have been avoided from the start-up, especially reduced work-in-progress (WIP) and personnel utilization. A result that differed from previous research made was the source and type of disturbance. Previous research showed start-ups commonly experience disturbances caused by late engineering changes, production technology, and supply of material which was not found at JCI. Furthermore, JCI managed the team of engineers and managers to work effectively with the start-up and had an excellent information flow. Level of skill seemed to be the most influencing factor for JCI's start-up. This result has not been found in other research. It is likely that this is caused by the Chinese labor market. Migrant workers, motivated with monetary incentives show a high likelihood of change job for even a slight salary increase, a problem found at JCI causing high personnel turnover. This affected the quality during the start-up and also today with extra cost for rework. Implementations made involved reducing personnel for reduced cost and improved efficiency. Reducing WIP resulted in increased floor space, increased inventory turnover and reduced material handling.

Keywords: Manufacturing start-up, start-up performance, start-up, learning curve, Chinese automotive industry.

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List of Abbreviations

JCI	Johnson Controls Inc.
VSM	Value stream mapping
NVA	Non-value-added (time)
VA	Value-added (time)
MNC	Multinational Company
JIT	Just-in-time
SOP	Start of Production
WIP	Work-in-progress

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1 INTRODUCTION

This chapter introduces the reader to the project, starting with a brief background of the company for which the thesis is written. It also outlines the topic of this report, the purpose and the problem definition. Key research questions that this thesis will answer will be presented followed by the limitations of the project. Lastly is an outline to the report to orientate the reader of the chapters included in the report.

1.1 JOHNSON CONTROLS INC.

Johnson Controls Inc. (hereafter JCI) is a global company, founded in America with roots back to 1885 with over 170 000 employees in more than 150 countries. JCI is a diverse company with four main business units; building efficiency, global workplace solutions, power solutions, and automotive experience. The building efficiency unit provides equipment for ventilating, heating and air-conditioning systems. JCI is the global leader in lead-acid automotive batteries with its power solutions unit. The global workplace solutions unit provides with corporate real estate, facilities and energy management for large companies.

The automotive experience unit is the global leader in automotive floor consoles, door panels, automotive seating and instrument panels. In this business unit, JCI has 240 plants worldwide and support all major automotive companies with solutions for car interiors. Its operations globally supply more than 50 million cars per year (Johnson Controls, 2015).

1.2 BACKGROUND

Geely is one of China's largest automakers but has since the past only supplied the Chinese market. In 2010, Geely acquired Volvo Cars from Ford with the purpose of opening up for foreign markets and acquire technology (The Independent, 2015). A few years after the acquisition, Volvo Cars opened its first manufacturing site in Chengdu, China. JCI is Volvo Cars' supplier of seating solutions and along with the new Volvo plant, JCI also opened up its operations in 2013 in close vicinity to the Volvo plant in Chengdu.

The final assembly of seats is in the Chengdu plant. JCI also has manufacturing in the neighboring city of Chongqing, where trim and metal parts are manufactured. Furthermore, most of the suppliers are located 300 km from the Chengdu plant. JCI's business office and R&D is also located in Chongqing, whereas the Chengdu plant only has manufacturing and staff for daily manufacturing operations. The Chengdu plant has two manufacturing lines, one for rear seats and one for front seats respectively. It is incorporating just-in-time assembly (JIT), closely working with Volvo with the same takt time.

Since the start-up, operations in Chengdu have stabilized. However, the company has expressed their concern regarding the utilization of resources, efficiency, and quality issues. These problems have become more evident when JCI is under pressure to launch new products, capacity increase and higher quality demands. For the reason of analyzing these problems and propose improvements, JCI has an interest in this thesis work.

During the start-up phase, many companies struggle to keep a disturbance free production. There are often uncertainties that need to be under control in order to ramp up to full production. For many companies, especially in machine intense production, the start-up phase can last for years (Hendersson, 1981). Almgren (2000) listed a set of disturbances that could be linked to the start-up phase in the automotive industry. To mention a few, these are quality of material, machine availability, operation performance, and level of skill.

Another aspect worthy of mentioning is the work of Wright (1936). He proposed a learning curve to predict cost of manufacturing in the aerospace industry. This model has proven to be applicable to other types of manufacturing than the aerospace industry.

Previous work covers the pilot production and start-up phase. This phase is defined as the time between the first manufactured product until the production is running as intended. JCI is already past this phase but is still experiencing disturbances even though the production can operate at full speed. It is therefore of interest to analyze the post start-up and draw conclusions if the disturbances are somehow connected.

1.3 PURPOSE

The purpose of this master thesis is to analyze JCI's operations on their seating production lines and connect this with previous research to evaluate if there are still disturbances from the start-up phase in the system. How these disturbances take action, what could have been done to avoid them and also how to improve operations. If possible, some or all of the improvement proposals will be implemented. The result of the thesis will be an analysis and improvement plan for JCI's operations and a literature review to connect previous and current research in the field of manufacturing start-up with the case of JCI.

1.4 RESEARCH QUESTIONS

A set of research questions are to be answered in this thesis to give a more structured view of the problem definition.

1. What does previous research tell us about the connection between present disturbances and the start-up phase?
2. What disturbances did JCI have during start-up and why were they present?
3. How were these disturbances solved?
4. What disturbances does JCI have today?
5. How can JCI's current operations be improved?
6. Has the start-up phase had an effect on the disturbances JCI is experiencing today? If yes, how has it had an effect?

1.5 DELIMITATIONS

Companies might encounter disturbances outside of the actual manufacturing plant, i.e. in their supply chain, but these disturbances will not be considered in this project, merely disturbances that can be observed in-house. JCI has trim and metal manufacturing at another site and these suppliers could be of interest to analyze, however, external suppliers will not be included.

Focus on improvements with a minimum or no cost will only be considered, as requested by the company. However, more costly improvements might be up for recommendation but will not be considered for implementation.

To get an overview of the whole of JCI's manufacturing operation, the analysis will not go beyond station level. Individual tasks will not be considered unless an improvement is needed on that particular station.

Many authors have performed research on what makes a successful start-up from a business point of view but this will not be covered in this report. The focus is on disturbances in manufacturing during start-up or post start-up.

1.6 METHOD

The project followed parts of a case study method developed by Yin (2014). The method includes both qualitative and quantitative data collection. Data was collected at JCI's plant in Chengdu, China during 5 months in 2015. Methods for data collection were literature review, unstructured and structured interviews, and internal documents such as production reports, quality reports, and data from the HR department. The data was used to analyze JCI's disturbances during the manufacturing start-up. To analyze JCI's operations today, value stream mapping (VSM) was used. Data in this stage was collected through time studies and extensive direct observations. To answer the research questions to connect the disturbances in the start-up with the disturbances today, the data collected was compared with information from the theoretical framework and other researchers' findings.

1.7 THESIS OUTLINE

Chapter 2 introduces the topic for the study to the reader and gives the necessary theoretical framework for the report.

Chapter 3 describes the research methodology used to complete the project. Also, motivation for chosen methods are outlined.

Results are presented in chapter 4 with data and other evidence

A discussion of the results id found in chapter 5.

Conclusions are found in chapter 6 with the conclusions drawn and also answer to the research questions.

2 THEORETICAL FRAMEWORK

This chapter first introduces a literature review over the previous research done in this field. Necessary theory regarding topics brought up in later chapters is also included. This is to assist the reader with sufficient knowledge to be able to interpret the results and follow the work performed.

2.1 TIME TO MARKET

Most industries today struggle with tough competition, especially in the case for consumer electronics and the automotive industry. The products do not only have to be competitive, also the firm's manufacturing processes has to be competitive. Product quality, cost, and time-to-market (TTM) are all essential for running a profitable business.

The concept of time based competitiveness was coined by Stalk (1988) and came after the advances in the Japanese manufacturing industry. After WW2, competition was merely a matter of innovation and marketing (Pawar et.al, 1994) and shifted to economies of scale during the oil crisis in the 1970s. The advances in Japanese manufacturing industry during this time meant that they could produce with low cost, quality, reliability, and could rapidly introduce new products to the market. A competitive advantage through TTM in the 1990s could have been the single most important competitive factor for manufacturers of all markets (Vesey 1992).

Cohen et.al. (1996) also stresses the importance of a TTM approach to competitiveness. He estimates that for everyday a new car release is delayed (for a 10 000$ car), this amounts to a 1 million dollar loss in profit. Also for the automotive industry, if companies launch a new product 6 months late, this will cause a 33% loss in profit. This figure will only be 3.5% if product development is 50% over budget but product is launched on time. Cohen (1996) also argues that there is a tradeoff between product performance and TTM. In many industries, the success of the product depends to high extent on the performance and features. Even so, if hitting the market too late, the company might miss the window of opportunity for making profit. The outcome of his research is a model framework for optimizing TTM and product performance target. However, he assumes the new product makes the old one completely obsolete, such as in the software market and cannot be applied to the suppliers in the automotive industry.

The role TTM has for companies' profit is stressed by many authors, researchers and practitioners. This is caused by the dramatic change in product life cycle times. Bullinger (1995) makes his case by analyzing the result of a survey of over 140 companies. The results showed a decrease in product life cycles for different industries. He also states the breakeven point has increased during the same period. Here, the profit window is the time between when breakeven is made and the life time of the product. The worst of all industries is suppliers for the automotive industry. Product life cycle time has decreased by 30% and the point of breakeven has increased by 50%. This truly is a dramatic change in the profit window with a total decrease of 80%. The results also showed that for the electronics industry, the life cycle time has decreased by almost 50% but breakeven point is much faster than for the automotive supplier industry.

2.2 THE LEARNING CURVE

A relevant research to this study is the learning curve. Wright (1936) proposed in his pioneering work that cost of manufacturing was a function of accumulated production volume in the aerospace industry. The cost (or man hours/aircraft) of aircraft manufacturing would decrease over time as produced units would increase. The aircraft learning curve he introduced is well known and has been topic for research by many authors (Baloff 1966, Argote 1990, Benkard 2000). Wright (1936) defined the learning curve as:

$$y = ax_i^{-\theta} \qquad (1)$$

Where y the number of man hours required to produce the x_{th} unit, a is the number of man hours required to produce the first unit, x is cumulative past output and θ is expressing how the labor hours reduce as the cumulative output increases. A general shape of the curve is seen in figure 1.

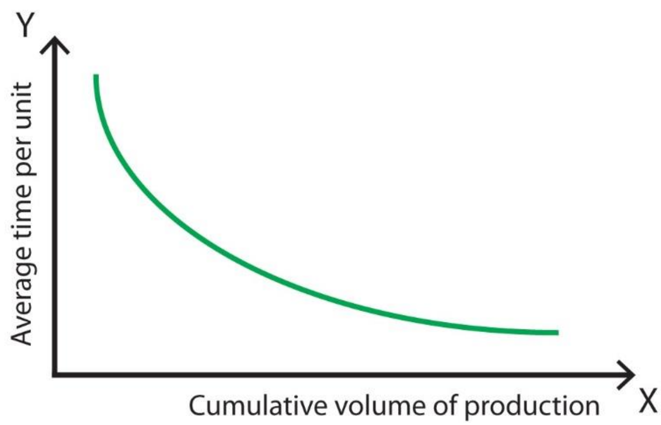

FIGURE 1 LTHE AIRCRAFT LEARNING CURVE

The learning curve was first introduced in the aerospace industry but has since then been shown to be applicable in other industries. Baloff (1966) reports that the learning curve has been used to estimate start-up costs in the electronics and textile industry. Similar industries as the aircraft industry, i.e. labor intensive industries can apply the model with good accuracy. However, Baloff suggests that the model extends beyond the labor intensive industries previously studied. Different industries will have different learning and is shown in the θ-factor in equation (1).

Benkard (2000) also discusses different forms of learning in his journal paper. Benkard states that learning in capital-intensive industries, learning is the result of tuning the production equipment. Output is surveyed when gradually tuning the processes for continuous improvement. Thus, learning comes from process changes whereas in labor intensive industries, learning results from operators' individual learning in performing tasks. Efficiency is achieved by multiple repetitions by the operator. Both types of learning can be observed in many industries.

Argote (1990) discusses that different learning is not only among different industries. Within the same industry and even in companies producing the same type of products a difference can be distinguished. This leads to the conclusion that organizational behavior and operations management have an important role in companies' ability to learn. However, Argote's results showed that cases studied still showed a learning curve but with different rate of learning.

2.3 Quality and Learning

Li and Rajagopalan (1996) presents the effects quality has on the learning curve and claims to be the first in conducting an empirical study on the topic. They propose that the number of produced non-conforming parts explains the learning curve effects better than cumulative past output. They give empirical evidence that companies that spend more resources on improving quality also have a higher level of quality and learning. Non-conformity is often taken seriously and is detected by managers early. Great efforts are taken to overcome the quality issues and therefore attention is drawn to the cause of the problems. Learning will be an outcome of the investigation of quality issues due to the improved understanding of the processes. These improvements can lead to more efficient processes using less labor hours and/or less machine time which can explain the learning curve effect. Li and Rajagopalan (1996) use empirical evidence to show that the connection between quality and learning is stronger than the connection between learning and cumulative output.

2.4 Manufacturing Start-up in the Automotive Industry

The most relevant research to this study is the manufacturing start-up in the automotive industry. Historically, most research has been in the electronics industry due to the rapid decrease in life cycle for products in that industry. Hence, manufacturing start-up is crucial in this industry to be able to make profit. The window of opportunity for making profits is gradually decreasing which was mentioned in previous section. More recently, studies have been conducted within the automotive industry (Surbier et.al. 2014).

The start-up phase is defined as the time between time-to-market and time-to-volume, i.e. the time when the production system is running at full capacity. Before this stage, product development has been completed and the necessary tests and pilot production is confirmed. See figure 2 for clarification. Many companies focus on reducing cost in product development but fail to include the cost of the manufacturing start-up which has great effect on the total development cost (Almgren 1999).

According to Surbier et.al. (2014), the start-up phase has certain characteristics which are a summary of other authors' research in the field. These characteristics of the start-up phase are:

- The level of knowledge is low about the production system and its processes.
- Low production output.
- Higher cycle time.
- Low production capacities.
- High demand.
- High disturbances in process, supply chain and/or product quality.
- Lack of planning reliability.

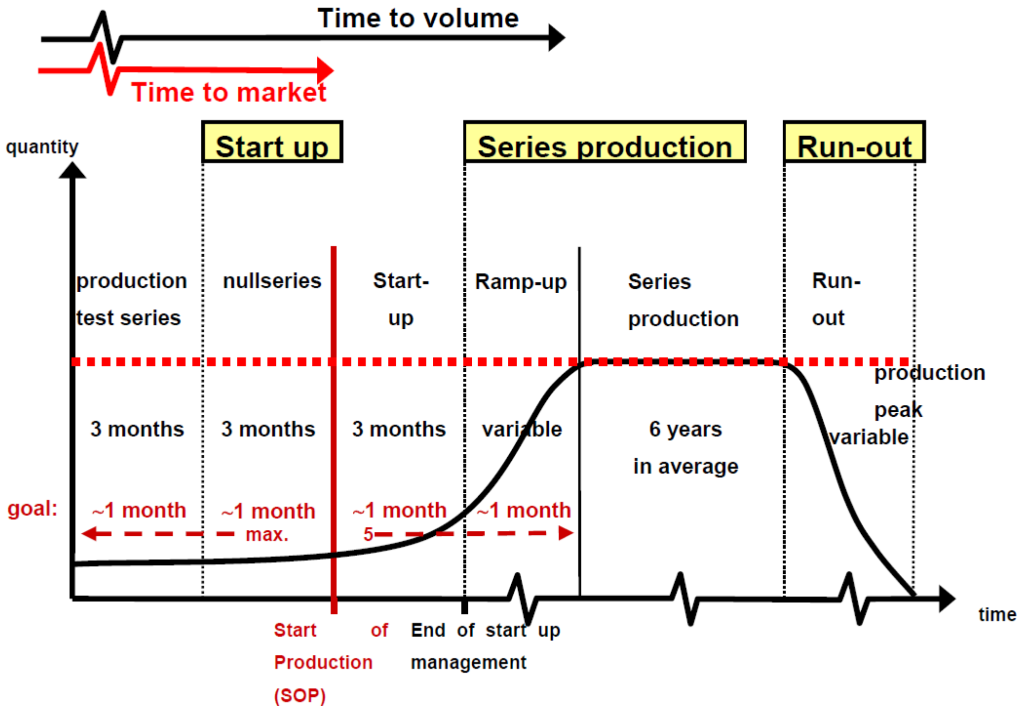

FIGURE 2 START-UP IN THE AUTOMOTIVE INDUSTRY AS DEFINED BY SUBRIER ET.AL (2014)

These characteristics cause many problems during start-up in all parts of companies. On product level, problems are found due to late engineering changes, product specifications are not thorough and maturity of the product. Lack of process maturity cause problems with slow set-up, insufficient manufacturability and bottlenecks in the process not detected during development. The logistics chain has to be completely rebuilt if building a new manufacturing plant at a new location but even if just a new product is introduced, one will encounter problems with the logistics. The suppliers also experience a start-up phase for new material and can have problems with deliverability and quality. There is also a lot of uncertainty in data and knowledge about costs for activities which cause problems in resource planning. Of course, a new plant or production line requires personnel that have little or no knowledge about the system and have to undergo training and lack thereof cause disturbances. Not only disturbances in quantity, also quality. Unforeseen causes of non-conformance are inevitable in a complex production system as in the automotive industry. Each department in a company need to communicate effectively to handle all disturbances. If R&D, manufacturing, management, logistics are not well coordinated, this will add to the time and cost of the start-up (Surbier et.al. 2014).

Henrik Almgren (1999) has in several case studies performed research of manufacturing start-up in the Swedish automotive industry. The purpose of his research was to understand the process of start-up better and investigate how production capacity and quality is affected by disturbances during manufacturing start-up. His work is highly relevant to the study in this paper which concerns disturbances and performance during start-up and post start-up.

Almgren (1999) defines two causes of disturbances within a production system. One is because the organization is not able to detect the conditions of what cause disturbances and the other being the organizations inability to take actions to prevent and correct these conditions. He also defines the most common sources and types of disturbances;

- Product concept (engineering change)
- Material flow (quality and status of material)
- Production technology (operation performance, machine capacity, and quality performance)
- Work organization (attendance, skill)

To measure these disturbances, Almgren (1999) proposes 4 KPI's as measures. The first one is straight forward and measures quantity performance by the ratio between number of produced products and number of planned products. He divides quality into two KPI's; product conformance and product quality. The former is from a customer point of view and measures the number of faults per unit of production and the latter measures the number of products without known defects compared to the total number of products produced. The last KPI measures efficiency and is defined as standard cost divided by actual cost and this was measured in Almgren's (1999) paper as overtime man-hours.

Almgren's (1999) results showed to be consistent with those of other author's and that over time, the measured KPI's follows a learning curve and that the slope of the learning curve is higher for more complex start-ups. He proposes to identify the sources of disturbances as early as possible in the start-up phase and make preventions or corrections.

2.4.1 Information During Start-up

There is less researched performed on the importance of information flow during start-up. Fjallstrom et.al. (2009) conducted a case study where the topic of information enabling production ramp-up was researched. Critical events regarding information was categorized into six different groups according to the case study conducted at a major Swedish car manufacturer;

- Suppliers/supply
- Product/quality
- Equipment/technique
- Process
- Personnel/education
- Organization

These categories as stated by Fjallstrom (2009) are summarised below;

Information types in the supply chain regarded what kind of error, delivery, and economic information for incoming material. Sources for this type of information were other people such as operators, managers and quality personnel. Also some information was attained from visual inspections.

Important information regarding product and quality was how to assembly for good quality, functionality of machines and what actions are to be taken for prevention. Sources here were mostly other people or documentation.

Information in the equipment/technique category is information of how to best make use of production equipment. The technical information about the equipment is known but how to operate it the best way is not. People with more experience or knowledge were the top information sources here. The importance of having input from more than one individual in this category was pointed out since information of this type is too complex for one person to have.

The process information has a broader frame than that of the equipment category but has some information overlap with equipment/technique. The production system as a whole and problems regarding it falls into this category. Due to the broad information in this category, most sources showed to be important, i.e. other people, visits to the shop floor, documentation, and own experience.

Information to the operators of how to avoid disturbances or how to act upon different situations and problems regarding how to educate the operators falls within the personnel/education category. Fjällström et.al. (2009) states that other people were the most used source for information in this category even though there were well documented education plans prior to the start-up.

The organization category has information about different working shifts (working hours, breaks takt time etc.). Information was mostly communicated via meetings and documentation.

What can be concluded is that mostly other people with more experience is used as information sources and this encourages team work when solving problems in manufacturing start up (Fjällström 2009). Team work enables problem solving to be more efficient with more input from a diverse group of people in a cross functional team. Many authors who mention information during start-up only highlights the importance with good information flow and cooperation between R&D and manufacturing departments but not during the actual start-up, more so in the product development phase (Surbier et.al. 2013).

2.5 Value Stream Mapping

Value stream mapping is a tool that can be used to identify and eliminate (or reduce) waste in most value chains. The method was introduced by Toyota's chief engineers Taiichi Ohno and Shiegeo Shingo, known as material and information flow mapping (Hines & Rich 1997). A central idea in the method is wastes in production systems and only to focus on what adds value to the customer. In the Toyota production system, there are 7 types of wastes that are necessary to reduce or eliminate to achieve a leaner organisation (Tapping et.al. 2002);

1. Overproduction. The worst type of waste. Only produce according to customers' demand.
2. Waiting. Inefficient use of time when products are not moving or being worked on.
3. Transports. Any movement of product can be seen as waste as it does not add value to the customer.
4. Inappropriate processing. When a process is overly complex for a procedure which requires less complexity. Also when machines and tools have poor quality, resulting in poor product quality.
5. Unnecessary inventory. Excessive inventory increase lead time, prevents the detection of problems, and use space on the shop floor.
6. Unnecessary motion. Occurs when operators have to reach, stretch or bend to pick parts or tools. Excessive motion leads to poor productivity.
7. Defects (rework). Producing defect parts leading to rework.

To this list, some authors add an eighth waste which is latent skill. Employees in an organisation often have more skills than their job requires and to not take advantage of this skill can be seen as a waste (Liker 2004).

VSM is one of the best tools to map a process and for identifying waste (Braglia et.al. 2006). The method is used to identify waste by analyzing operations categorized into three types (Hines &Rich1997);

- Non value adding
- Necessary but non-value adding
- Value-adding

The first two can be any form of activity within the 7 wastes described earlier and should be eliminated or reduced, whereas value-adding time is what is sought for. VSM follows five steps in order to do this (Tapping et.al. 2002);

Planning. Here you choose the product or product family you want to map the value flow of. Since it can be very tedious to map all variants and all models you should choose the one which represents the current state the best and is most beneficial. This is often high volume products and variants. Also to set up objectives and choosing a team to perform the VSM is done during this stage.

Draw current state. Together with a team with members that represent all parts of the organisation you draw the current state of the operations. With a pen and paper approach and using symbols for different activities the map is drawn to visualize the value flow of the chosen product or product family. The following step includes collecting data for the map. All steps in the flow of products are measured with cycle times for assembly, process times, inventory levels, stock levels, delivery times and shipping times etc. Also the information flow is drawn on the map. Appendix A shows an explanation of symbols commonly used.

Times measured or collected are categorized into VA/NVA to allow for detection of the most wasteful activities. Ways to eliminate or reduce these activities are developed to draw a future state map. The last step is then to implement the changes made by communicating ideas through the future state map.

Figure 3 shows an example of a value stream map of a simple production with 4 processes.

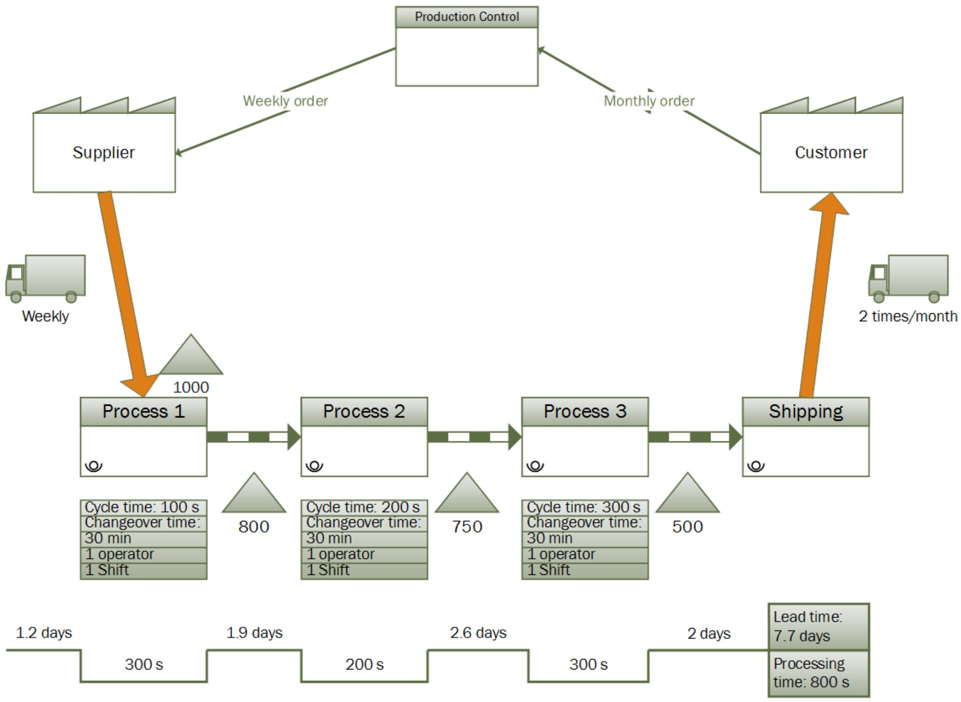

FIGURE 3 EXAMPLE OF A VALUE STREAM MAP OF A SIMPLE PROCESS

The map is rather simple but for more complex productions system, the map can get increasingly large. The map shows how material flows from supplier, through the processes and onwards for shipment to customer. Information flow is also mapped where electronic orders are processed by the production control system. For each process and inventory the material passes through, cycle times, waiting times and other data is measured. The timeline has one "up' segment and one "down" segment which indicates if the time is value adding or non-value adding. Total lead time in this example is 7.7 days and processing time is merely 800 seconds, indicating wastes in holding excessive inventory.

2.6 THE CHINESE LABOUR MARKET

Relevant for the study is the nature of the Chinese labour market. This is especially a concern during a start-up as it can have an effect on learning within organisations. In a critical phase as manufacturing start-up where the whole organisation is learning, having a high employee turnover adds to the problems of learning.

It has been reported high employee turnover in joint ventures between multinational companies (MNC) and Chinese companies (Khatari et.al 2001). High labour turnover rates have caused low productivity, poor quality and reduced output (Jiang et.al. 2009). Workers have to be trained to an accepted level of skill which is costly and time consuming with an increasing employee turnover. Without a necessary level of training, quality issues can increase dramatically.

Migrant workers from rural parts of China move to more developed areas seeking job opportunities. More developed areas are the coastal area and also Sichuan province in China's inland. Large industrial clusters with companies are common with a large accumulated labour pool. Job hopping is common where firms poach workers by offering higher pay or better positions. MNC's in China seek a specific type of labour force that is mobile, have low salary expectations and willing to work long hours, which are characteristics for migrant workers coming from poor rural parts of China. Motivation and incentives for this kind of labour is often monetary with base salary, merit pay and bonuses (Chiu et.al. 2002).

3 METHODOLOGY

This chapter describes the research approach and procedures that were used in order to complete this project. Steps carried out in the project will be presented, as well as data collection methods and methods used for analyses.

3.1 CASE STUDY METHOD

This project followed a case study methodology developed by Yin (2014). The method is a powerful tool for performing research and is recognized by many researchers (McCutcheon et.al. 1990, Almgren 1999). The purpose of using a case study method was to have a broad data collection with more data sources and forms of data than other methods. This was to get a richer and well prepared case study to be able to solve real problems in operations management (McCutcheon et.al. 1990).

The case study method proposed by Yin (2014) uses multiple sources of data, both quantitative and qualitative and is best used when your research questions are in terms of *how* and *why* around a certain occurrence. The method is applicable to this study since it aims to investigate why and how JCI's disturbances can be connected to the known problems in a manufacturing start-up.

3.2 CASE STUDY PROCESS

Yin's (2009) case study method includes six steps which are conducted in a linear process with some iterative elements. The road map for the case study can be seen in figure 6. To use the whole of Yin' method was too rigorous for this thesis work. The parts used are plan, design and the data collection from Yin's method.

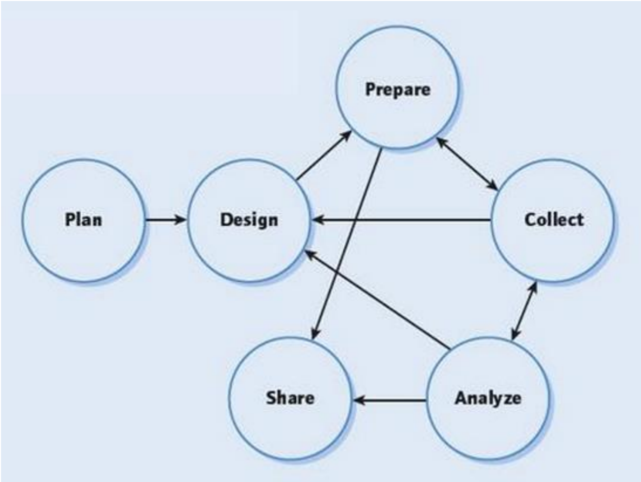

FIGURE 4 CASE STUDY ROADMAP ACCORDING TO YIN (2014)

3.2.1 PLAN

The first step in the process is to plan your research and to conclude weather conducting a case study is relevant to your research. As mentioned before, if the research aims to answer explanatory questions such as *how* and *why* something has happened, then a case study method can be used. For planning the project, the most important step was to set up the research questions. For JCI's operations in Chengdu, the start-up phase was to be studied. Not only buy investigating what disturbances JCI had but also why they have occurred and more in particular; how they are connected to the start-up phase. With these research questions, a research in the form of a single case study was chosen.

3.2.2 Design

Yin (2014) notes 5 important steps in designing a case study research;

1. A case study's research questions
2. Its propositions
3. It's units of analysis
4. Linking data to the propositions
5. Criteria for interpreting the findings

The research questions have already been covered in previous section and are mentioned here again to note the importance of asking the right questions for your study and that the form of your questions will determine what research method to use. However the research questions do not by themselves point out what should be studied. For this reason, a proposition for the research questions was stated in order to focus the study on certain areas of JCI;

JCI's disturbances today are caused by inefficient solutions to the start-up problems leading to inefficiency in personnel utilization, material handling and excessive inventory.

This proposition points out what to study in the case of JCI to help answer the research questions. It proposes that JCI have inefficiencies in certain areas which led to the decision to analyze the value flow in JCI.

The unit of analysis in this case study is straight forward. The research questions are only considering the manufacturing start-up in JCI's plant in Chengdu and therefore only data that can be collected or measured within the plant will be considered. A broader study with other start-up factories was never considered.

The data to be collected needs to be linked to the research questions and the proposition this step is covered in the data collection chapter. Criteria for interpreting the findings were set up to verify the results. This involved comparing the results with other researchers' work to have more credibility in the findings.

3.2.3 Literature Review

The purpose of the initial literature review was to find existing research regarding disturbances in manufacturing start-ups to conclude if there was a gap in the literature worthy of performing research about. The conclusion of this phase was that previous research was mostly concerning either machine intensive production processes or car manufacturers, not first tier suppliers. Also no research could be found of the post start-up phase and how problems here can be connected to the start-up phase. The initial literature helped shaping the research questions. After the initial stage, the literature review conducted aimed to build a theoretical framework for which analysis and discussion could be based on. This work was carried out in parallel throughout the project. In the initial stage the factors that cause disturbances in a startup was not known. With more knowledge, the literature review shifted to be relevant to the findings made. The last part of the literature review was used to verify the results. The results and findings were compared to other research in the same area to verify the reliability.

3.3 Data Collection

Both qualitative and quantitative data was collected from mainly 4 sources. These are in chronological order as they presented in subsequent chapters; Interviews, direct observations, internal documents, and time studies.

3.3.1 Interviews

Qualitative data was collected through an extensive amount of interviews with employees in various departments of the company. Initially in the project, interviews were in the form of unstructured interviews. This type of interview is normally used when the interviewer has limited knowledge about the topic. The interviewer asks the interviewee a broad question about the topic and then lets him freely talk about the topic. From this point, the interview is transformed into discussion about the topic. A clear advantage of this is that the interviewee can talk about what he sees most important. On the other hand, there is a risk that the interviewee gives a biased view. This risk was considered low since information was collected from many employees, in different positions within JCI and reliability was established by comparing the interviewees' answers. This approach was successful in the beginning of the project to establish a network for data collection and understand the work procedures at JCI. In the initial stage, interviewees were asked about their experience in the start-up and were allowed to talk freely about their work content and observations.

In a later stage the interviews took a structured form where questions were prepared in beforehand for the interviewee to answer. At this stage, more knowledge was obtained and more detailed and structured answers were required in order to address the research questions. Focused interviews have the strength that it forces the interviewee to focus on the case study topic. It also provides explanations as well as personal views (Yin 2014). The concern at this stage was unreliable answers due to poor recall but again, information was crosschecked with multiple sources of information.

For both unstructured and structured interviews, personnel from product development-, manufacturing-, logistics-, HR-, management-, quality-, and finance department were interviewed. The interviews also included some operators.

3.3.2 Direct Observations

With the purpose to gain a better understanding of JCI's operations, the method of direct observation was used. This approach is well known in lean production and known as *Genchi Genbutsu* which centers around the concept of seeing problems first hand by 'go see for yourself' (Marksberry 2011). This method helped the understanding of operators' work content and more importantly for this study, the material flow on the shop floor. This method showed to be most valuable to analyze disturbances in JCI's current operations. Direct observations where made throughout the project in initial understanding, analysis and verification. The method allows for observations in real time when disturbances occurred and resulted in both qualitative and quantitative data.

3.3.3 Internal Documents

To analyze the manufacturing start-up at JCI, data was collected from internal documents. Since data from the start-up phase could not be collected in real time, historical data was collected from various sources within the company. This type of data was valuable to the case study as this data was not created as a result of the case study allowing to have unbiased data (Yin 2014).

Historical data of produced seats on a weekly basis was collected from the logistics department. It proved to be challenging to collect this data since data was missing from critical weeks during the start-up. This data was completed by data from the finance department. This data was not the number of produced seats in the missing weeks, but the number of sold seats to customer.

Data regarding quality was collected from the quality department. This data included quality reports on a weekly basis and also customer audit reports.

The extra cost of manufacturing was calculated from the number of extra hours of overtime for each week and collected from the HR-department. This metric was also used by Almgren (1999) to show the extra cost of manufacturing during the start-up. Also extra personnel for checking quality and correction work were used as a measure for extra cost of the start-up.

3.3.4 Time Studies

Time studies were conducted to measure the flow of products through the system. Standard times were not used in any part of the manufacturing and effort was put into this step to give a reliable reflection of the real situation. Times were used to complete a value stream map of JCI operations. This step is further explained in subsequent chapter.

Times were measured with a digital stop watch and during normal production conditions. Assembly times for both the seat models K413 and L421 were measured and to establish reliability, mean times with 5 samples were used.

3.4 Value Stream Mapping

Value stream mapping (VSM) was used to analyze JCI’c operations today. The method also created a valuable insight in the production system by extensive direct observations. VSM is one of the best tools to map a process and for identifying waste (Braglia et.al. 2006). To address the research questions, VSM can show where JCI have inefficiency in waste, and more specifically if the wastes are caused by disturbances from the start-up. This was done by comparing the findings from the value stream map by the data and information from the start-up, collected through internal documents and interviews. The theoretical framework and findings from other researchers’ work was also used for verification. The methodology for the value stream mapping at JCI is explained in subsequent chapters and the general approach for value stream mapping is explained in the theoretical framework.

3.4.1 Planning and preparation

The value flow for the seat models L421 (S60L) and K413 (XC60) were chosen for mapping. For these models, the value stream for both front seat and rear seat were mapped. Both models have a small number of variants but these were not differentiated due to the similarity in assembly. For instance, a model with a different trim (different color or material) will use the same resources, follow the same assembly sequence, and material flow is the same. The planning was communicated with JCI's senior management to get in line with the company's interests.

3.4.2 Current State Value Stream Map

JCI provided with a manufacturing engineer and the production manager to take part of a VSM-work shop. The workshop was held on several occasions during the first weeks of the project. During the workshops the value stream was mapped making use of post-its and magnets on a whiteboard. The post-its represented activities in the value stream, buffers or inventory and magnetic arrows were used to visualize flow of material or information. Activities were recorded with data metrics to be measured or collected later such as cycle times, inventory levels, value-added or non-value-added times (VA/NVA). In collaboration with the JCI's engineers the map was completed as detailed as possible. The map vas documented in a digital version, using the software Microsoft Visio. Data was imported to Microsoft Visio using Microsoft Excel. The reason for this was to have a map that could be communicated easily with personnel not present at the workshop. Both Microsoft Excel and Microsoft Visio are commonly used within the industry and this being the decision maker for what software to use.

Having finished drawing the map, data was collected to complete it. The procedure for time studies is explained in previous chapter. A large amount of direct observations were made during this step as an extensive amount of time was spent on the shop floor. Apart from measuring cycle times, buffers and material in inventory were counted. Due to the large number of activities in the value stream, the VA and NVA times for each assembly station could not be measured. Historical data was available where VA and NVA times had been measured in the pilot production. The proportion between VA and NVA times from this data was used and applied to the measured cycle times for the value stream map.

3.4.3 Analysis of the Current State

When the necessary data was collected it was analyzed using Microsoft Excel. Charts and tables were produced to evaluate today's operations at JCI. The aim at this step was to detect wasteful activities by looking at activities with high NVA times and activities contributing the most to the total throughput time. Results from the theoretical framework were also used to assess what data to look further at and how to analyze it.

3.4.4 Future State Value Stream Map

The outcome of the data analysis was a base when drawing the future state map. Here, wasteful activities were eliminated. This step included a lot of interviews with department heads to figure out cause of the waste and what changes that could be made. Especially the causes of the wastes were investigated further since it was important for this study. Thus, the causes were investigated for two reasons; understand them better to solve them and also to analyze if or to what extent they were connected to the start-up phase.

3.4.5 Working Towards the Future State

The future state value stream map was communicated with JCI's program manager, plant manager and manufacturing engineers to work out an action plan to implement the most wasteful activities. The limitations for this work were set according to the time plan for this case study's duration. Improvements that could not be finished within the time frame for the project were not considered for implementation at this stage but were noted by senior management for future implementation.

3.5 Verification

Results were evaluated for reliability by comparing them to other researchers' findings and theory on the subject. Qualitative data collected through interviews was suspected to have less reliability and were therefore always crosschecked with other sources of information. Since the data collected for the value stream map only gave a real time state of the operations at the time of measurement, several sample times were measured throughout the study to add more reliability. By implementing some of the changes in the future state map, a better understanding of the wastes was achieved. This helped analyzing to what degree they could have been avoided in the start-up. Some of the results will also be compared with JCI's production site in Sweden.

4 RESULTS

This chapter presents the results of the data collection and analysis. Some discussion of the results is brought up in this chapter but the results are discussed in a broader context in subsequent chapter.

4.1 JCI OPERATIONS

JCI's Volvo operations have manufacturing sites in three countries. The largest factory in Torslanda, Gothenburg supplies Volvo's main facility. Other facilities are the one in Ghent, Belgium which manufacturer seats for a few of Volvo's models. In China, JCI started production in late 2013 in the mid-west city of Chengdu to supply Volvo's first manufacturing plant in China after Geely acquired Volvo Cars. There is a planned start of production this year (2015) in a newly built facility in the north east of China.

This case study was conducted at JCI's Chengdu facility. The plant manufactures complete seats for the Volvo models S60L and XC60. JCI's model names are L421 and K413, respectively. These denominations will be used throughout the report. Figure 4 shows the different models.

FIGURE 5 L421 (S60L) SEAT (LEFT PICTURE) AND K413 (XC60) (RIGHT PICTURE)

As of March 2015, JCI Chengdu has 206 employees, where about 150 are blue collar workers. Start of production for L421 was week 45 in 2013 and week 38 in 2014 for K413. Both models are assembled on two production lines. One for front seats and one for rear seats. The number of variants are low, with the main difference being the trim used or the number of electric components for shifting position of the seat. Furthermore, the lines operate at a speed of 30 cars per hour (takt time 120 seconds) and operate by just-in-time towards customer. Most operations are manual assembly with other operations outsourced or having internal supplier. Stamping, welding and painting of front seat metals are outsourced whereas rear seat metals are manufactured at JCI's metal plant 300km from Chengdu. This is also where the trims are manufactured. Most suppliers are localized within a radius of 300 km and with only a few suppliers from the EU (seat belts and airbags). Apart from the two production lines, there's also a preassembly area which supplies the lines with material. Foam for cushions and backrests are currently being manufactured in another facility but are scheduled to move in-house in late 2015. For an overview of the layout in the factory, see Appendix B. A closer look at the layout for the two lines and the preassembly area can be seen in figure 5.

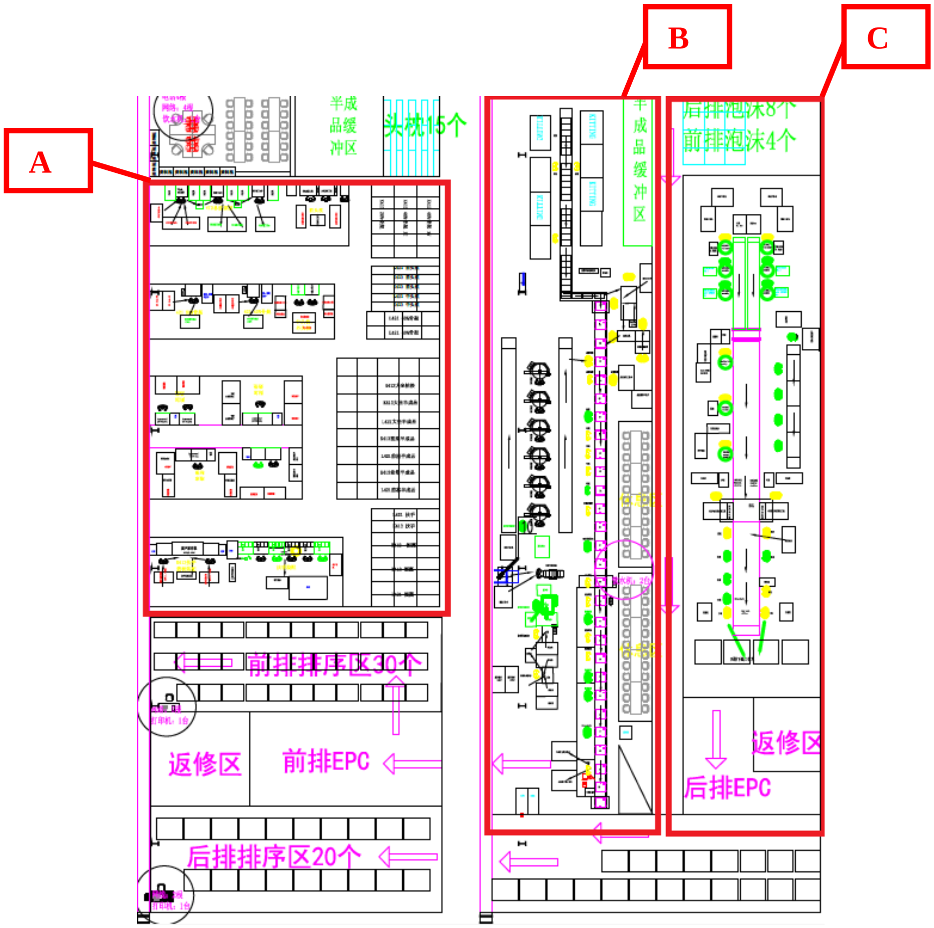

FIGURE 6 LAYOUT AT JCI CHENGDU

In the figure, section A is the preassembly area, section B is the front seat line and section C is the rear seat line. In 2014, JCI's output was about 33 000 cars and Volvo's has a goal to produce 200 000 cars by 2020. Demand has been increasing since the start-up and will continuously do so. Volvo as a customer is demanding reduced cost and improved efficiency, and quality and work closely with JCI

4.2 START-UP PERFORMANCE

In this chapter, JCI's performance in the start-up will be covered. Quantity performance, quality performance and extra cost of the start-up will be covered in different subchapters.

4.2.1 QUANTITY PERFORMANCE

JCI was not able to meet targets during the first six weeks after SOP and capacity loss was covered by working overtime. After week six, JCI could meet customer demand and follow the ramp-up of Volvo without overtime. The start-up performance for L421 is visualized in figure 7. It shows weekly output from SOP to 35 weeks after SOP.

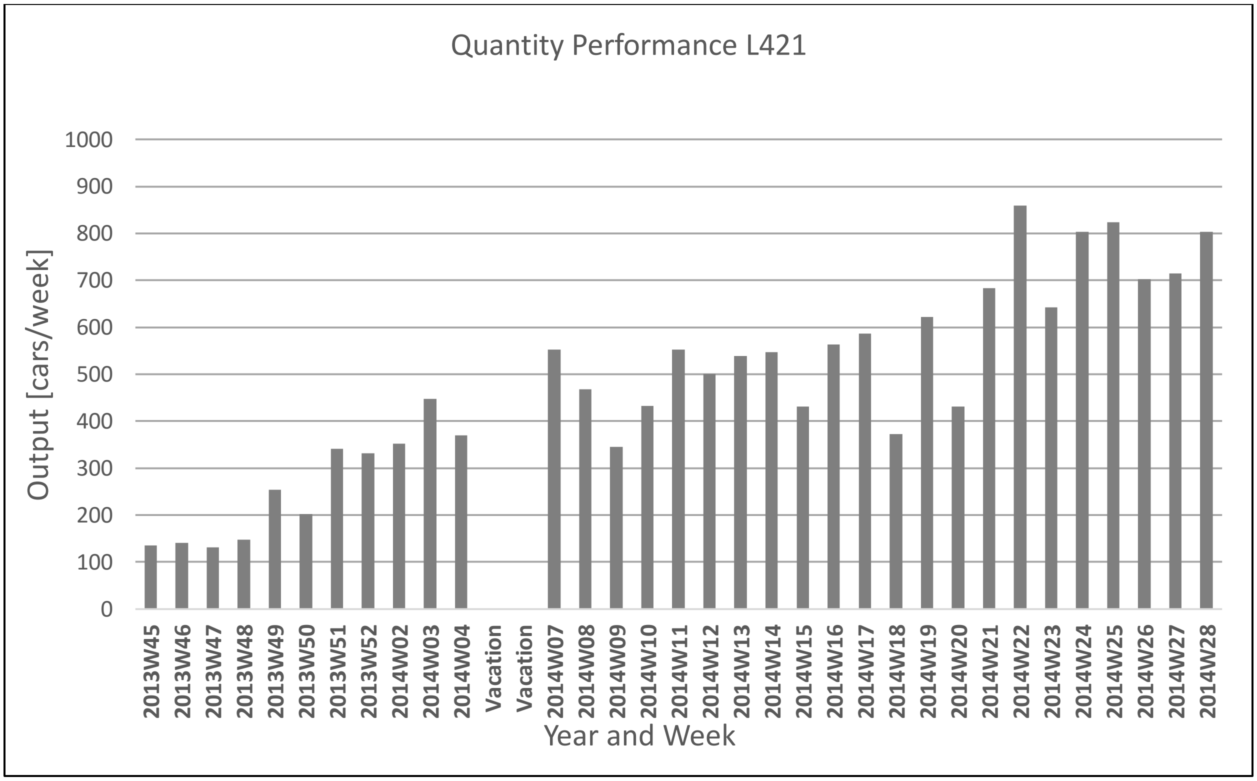

FIGURE 7 CAPACITY PERFORMANCE L421

During the start-up of L421, there were mainly 3 reasons for lost capacity; production technology, materials supply, and personnel. The production technology had some minor breakdowns and caused stoppages but no to a large extent. During interviews, maintenance personnel stated that there were breakdowns but they could be repaired easily and they did not cause major capacity loss. Materials supply caused some capacity loss during the start-up, as expressed by senior managers during interviews. Most of the problems with the materials supply were rooted in the quality. Poor quality in incoming material caused re-work which ultimately led to capacity losses. However, suppliers' delivery performance was good during the start-up and did not cause any capacity losses due to lack of material. The source that caused most disturbances during the start-up, affecting capacity performance was personnel. Training of personnel had been lengthy prior to the start-up, however, when running at full speed, operators failed to assemble at takt time. Experienced operators could also have detected poor quality in incoming material, thus some of the problems with materials supply could also be caused by level of skill of the operators.

The second start-up at JCI was for the model K413 which took place in week 38 of 2014. After the vacation (week 29), some test series was produced before SOP in week 38. JCI managed to meet output targets from customer during all weeks, thus no overtime needed. Volvo's takt time at this time was 120 seconds or 30 cars per hour, giving a weekly output of 1200 cars with eight hours work time per day. Six weeks after SOP for K413, this target was achieved by Volvo. The weekly output during the K413 start-up can be seen in figure 8.

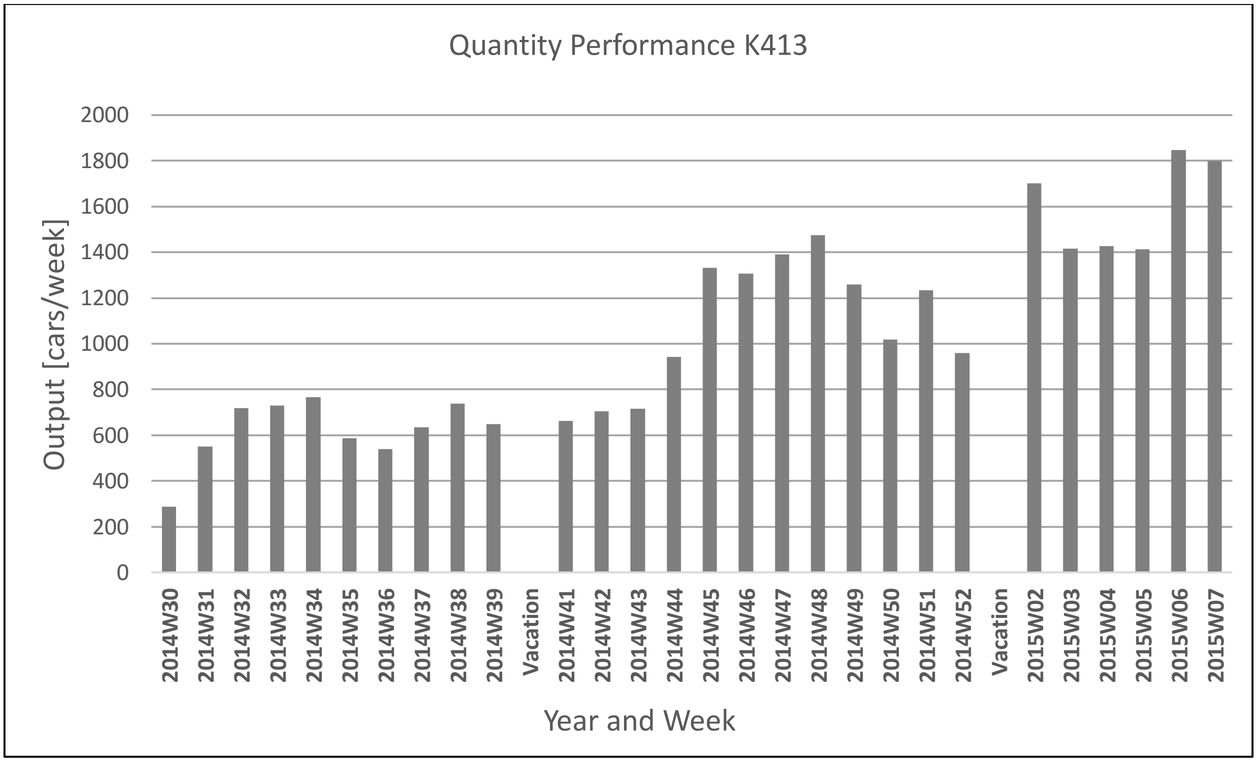

FIGURE 8 CAPACITY PERFORMANCE K413

Even though there were no capacity losses during the start-up of K413, disturbances could be felt in the same areas as for L421, although not to the same extent. During this start-up, the major cause of disturbance was personnel. The new model could not be built to acceptable quality by operators which led to re-work.

4.2.2 QUALITY PERFORMANCE

The product conformance was measured by weekly audits. Target for quality was set per month rather than per week. Figure 9 shows the results for the monthly audits since the start-up. Bars above the dashed line represent a failure in meeting quality target, whereas bars under it represent acceptable quality levels. The figure shows demerits per car monthly.

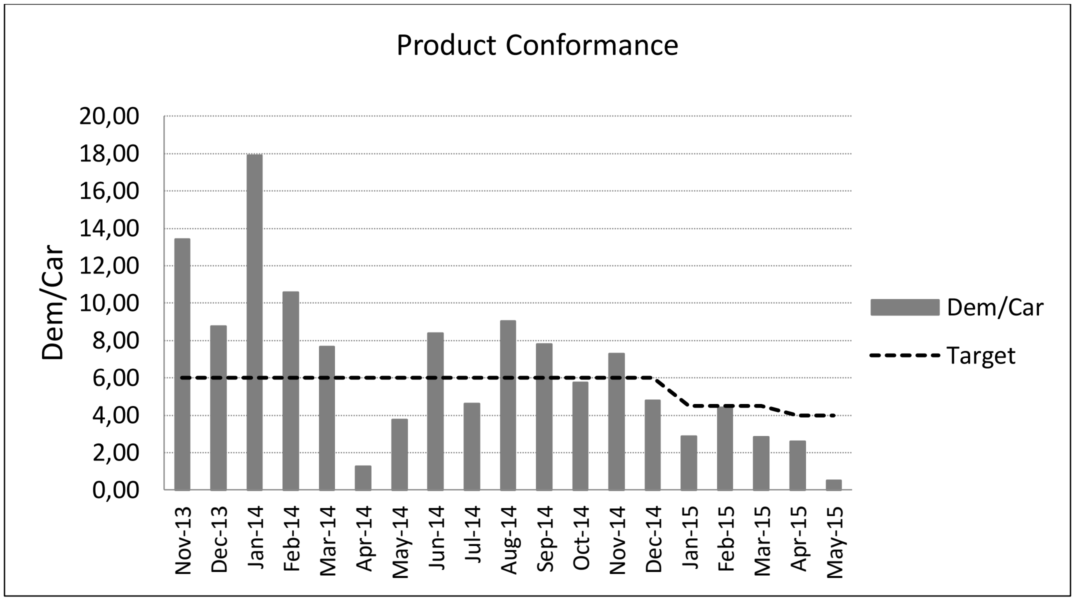

FIGURE 9 PRODUCT CONFORMANCE

The result shows that quality deviated from targets the first five months since the start-up and more than a year until targets could be met in more than 2 consecutive months. The launch of K413 in September (pilot production in august) was a reason for missed targets during these months. Issues of non-conformance were mostly demerits in the trim surface with scratches, folds, wrinkles, burn marks, and poor surface quality. These quality issues had two main causes; personnel and material supply. Personnel caused wrinkles and folds in the trim when assembling poorly. Many of the issues could be traced supplier of the back to the trims where surface quality was poor with scratches and other defects.

Another measure for product conformance was monthly rejects from customer with set targets for the number of rejects per 1000 cars (front seats and back seat). The results from this are shown in figure 10.

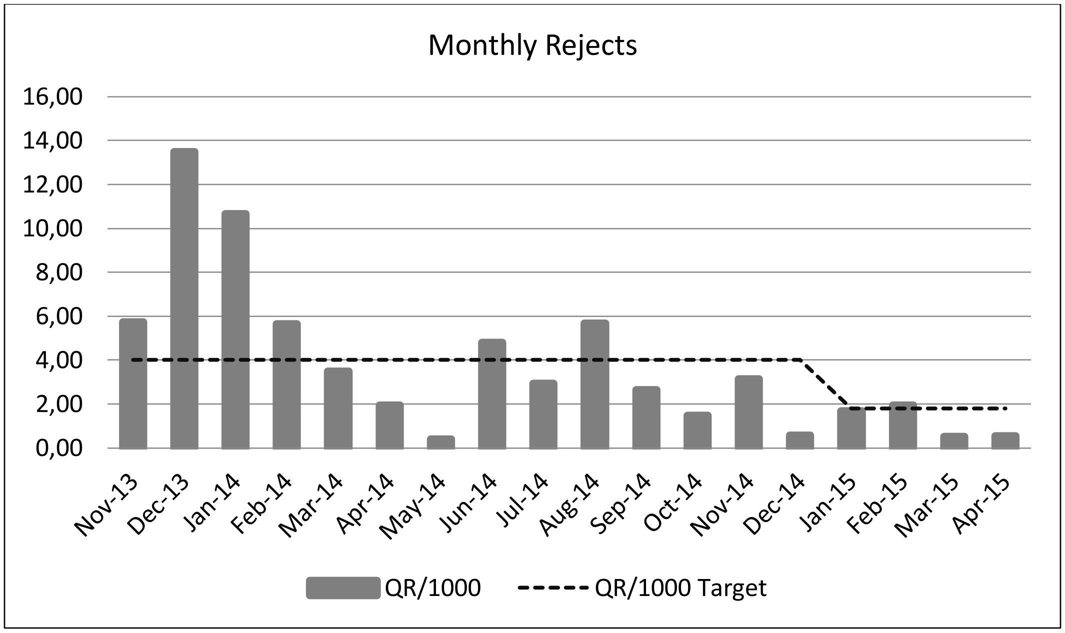

FIGURE 10 REJECTED PRODUCTS PER MONTH SINCE START-UP

Since these are rejected seats from the customer, more resources were used to find root causes and implement change. The results show similar to those for product conformance where a peak can be observed when K413 had test series in August 2014. The causes of rejects were the same as for demerits in product conformance with quality in incoming material and also personnel skill.

4.2.3 COST OF START-UP

Lost capacity in the start-up was solved by working overtime. This was common during the first six week after SOP. No data could be collected of how many extra man-hours were needed to make up for lost capacity. However, interviews with senior managers highly involved in the start-up claimed that 30 to 35 extra man-hours per week were common during the first six weeks. This number can be considered huge since it corresponds to almost an extra working shift per week in over time.

A major extra cost for the start-up was the cost of quality. To meet quality targets, extra personnel were hired to check finished products for quality and to correct mistakes or preform re-work. Extra personnel were hired to the logistics department for inspection of incoming material. At the time of this study, these personnel were still working to enable quality performance. The combined work force for quality checks and material inspection amounted to 15% of the total blue collar workforce. This number had only increased since the start-up. With increased quality demands from Volvo and suppliers' failure to deliver material with acceptable quality led JCI to hire extra personnel.

JCI globally has a business standard called BBP (Best Business Practice). This practice includes internal metrics that can be compared among all of JCI's businesses for productivity, profitability, efficiency etc. to allocate resources. With these metrics, given a type of seat with a certain complexity level, the number of operators needed can be calculated. BBP for a seat with complexity level of L421 and K413, with today's capacity demand is 75 operators. This is also the number of operators Volvo pay for. At the time of this study, JCI had around 150 operators. These extra operators can be seen as an extra cost of the start-up since all JCI startups strive for keeping BBP.

4.3 Johnson Controls today

As described in the methodology chapter, JCI's operations today were analyzed using VSM. The results from this process will be presented in this chapter.

4.3.1 Current State

The current state was analyzed using VSM for both front-, and rear seat lines. For a detailed view of the maps, see Appendix C and D. Due to the amount of data the maps contain; only critical parts will be presented in the report.

See figure 11 for an overview of the value flow for the front seat line.

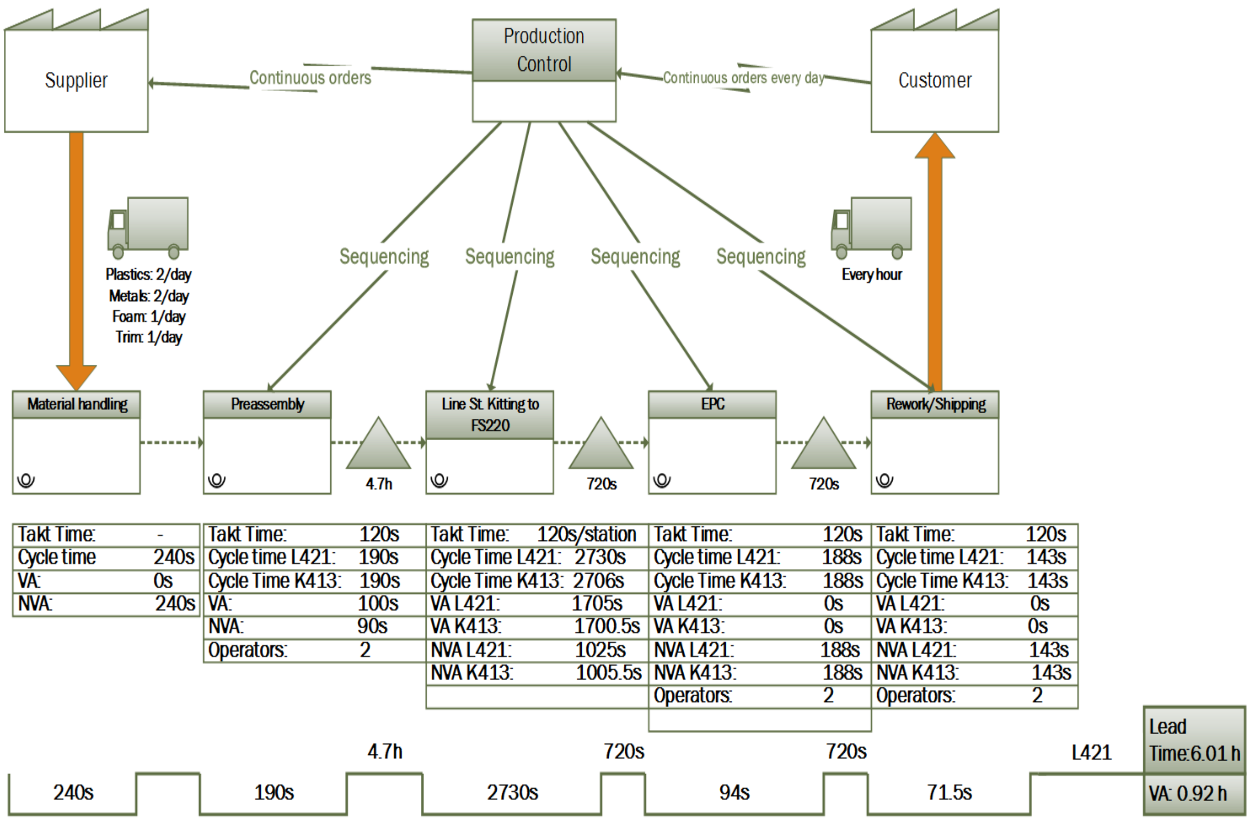

Figure 11 Simplified value stream map of the front seat production

The map describes the flow of material and information in a broader view and will be used for presenting the results. Material is delivered from customers once or twice daily depending on what type of material. It is then handled where material is unpacked, checked for quality, placed on carriers and finally stored in a supermarket or storage area. Parts of the seat are assembled in the preassembly area before stored, waiting to be processed at the line. Material is kitted into kitting boxes which follows every pallet on the line. Furthermore, there are 22 stations on the front seat line. Finished seats are moved from the line into the EPC area where operators perform 100% quality check. Depending on the level of quality, seats are either sent for rework/correction or straight to shipping. All seats are produced in sequence with JIT sequencing from customer. The rear seat line has nearly identical flow and will not be visualized in a simplified value stream map. For details, see the full value stream map in Appendix D. Significant differences are that the rear seat line uses line stocking instead of kitting, more parts are made in the preassembly and the quality check (EPC) has more personnel and has longer throughput time.

4.3.2 ANALYSIS OF CURRENT STATE

The most serious wastes in the systems could be detected in mainly 4 areas:

- Material handling
- Low utilization of personnel (waiting for material)
- Checking for quality
- Excessive Inventory

4.3.2.1 MATERIAL HANDLING

All material handling is non-value added time as it does not add value to the customer. Non-value added time could be observed at JCI when unpacking material and quality check of material. Also the movement of material from incoming boxes onto trolleys or carriers to be sent to the line or preassembly area. Most material is delivered in disposable packaging where logistics personnel have to handle scrap packaging after unpacking. Waste in this activity was especially observed for bulky material such as frames, chassis, and trim. Since the incoming packaging for these materials have few parts per package, the ratio between time spent unpacking and time spent on handling scrap is low. Also, additional personnel are used for sorting used packaging for recycling.

4.3.2.2 PERSONNEL UTILIZATION

Low utilization of personnel could be observed and measured when collecting data for the value stream map. Measuring the cycle times showed the front seat line to have stations which were heavily underbalanced, resulting in non-value added times when operators were waiting for material. This can be seen in figure 12 where the cycle time for each station is visualized. The takt time (120 s) is also shown.

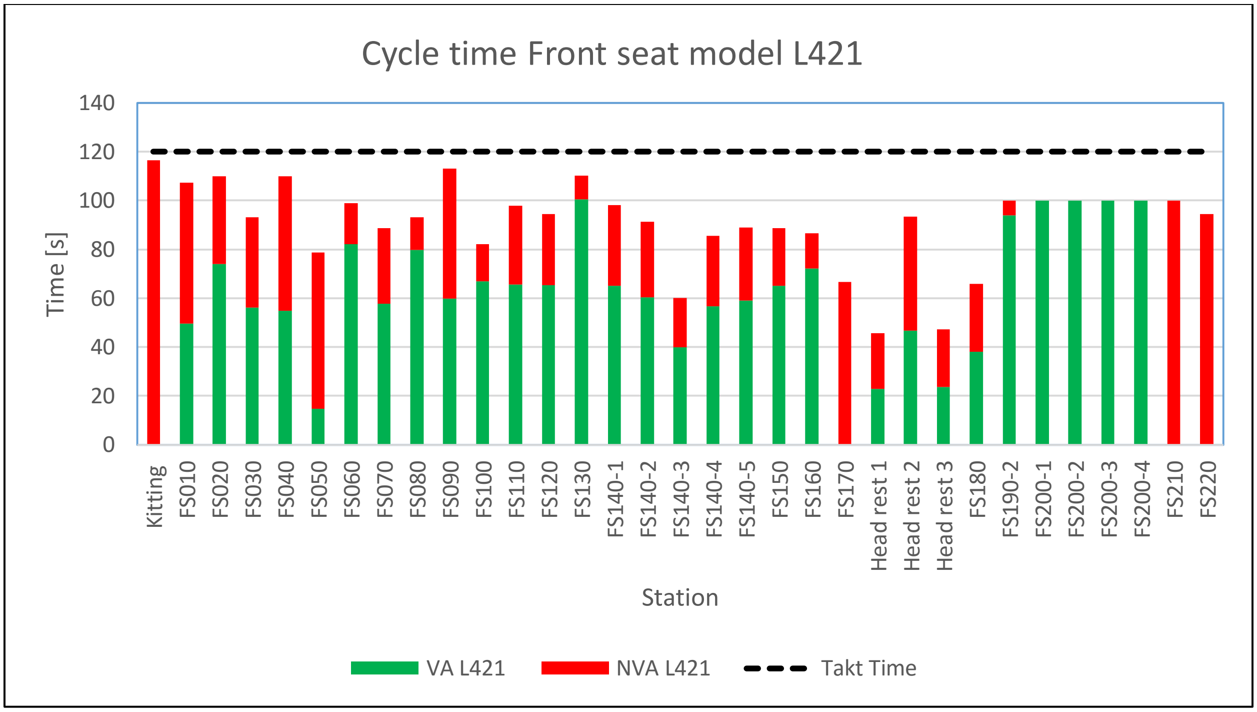

Figure 12 Cycle times for each station on the front seat line

Here, the cycle time for all stations have been measured and also the work has been categorized into value added (green part of bar) and non-value added (red bar). There is additional non-value added time when operators wait during the time between the cycle time and the takt time. The non-value added time observed in the performed work was mostly necessary work (picking of material etc.). Figure 12 shows cycle times for front seat L421 but can also represent K413 since the assembly operations are nearly identical. The average balancing for L421 and K413 is 76% and 75%, respectively. During the development phase, JCI's aimed to have 85-90% balancing. Utilization could be better and critical areas are the head rest assembly and stations proceeding it and also FS180. Two operators in the head rest assembly are working less than 40% of the takt time. Furthermore, FS180 is not only underbalanced, a majority of the cycle time the operator waits for an automatic test to finish.

Figure 13 shows the cycle times for each station on the rear seat line, with the same measurements as for the front seat line in figure 12.

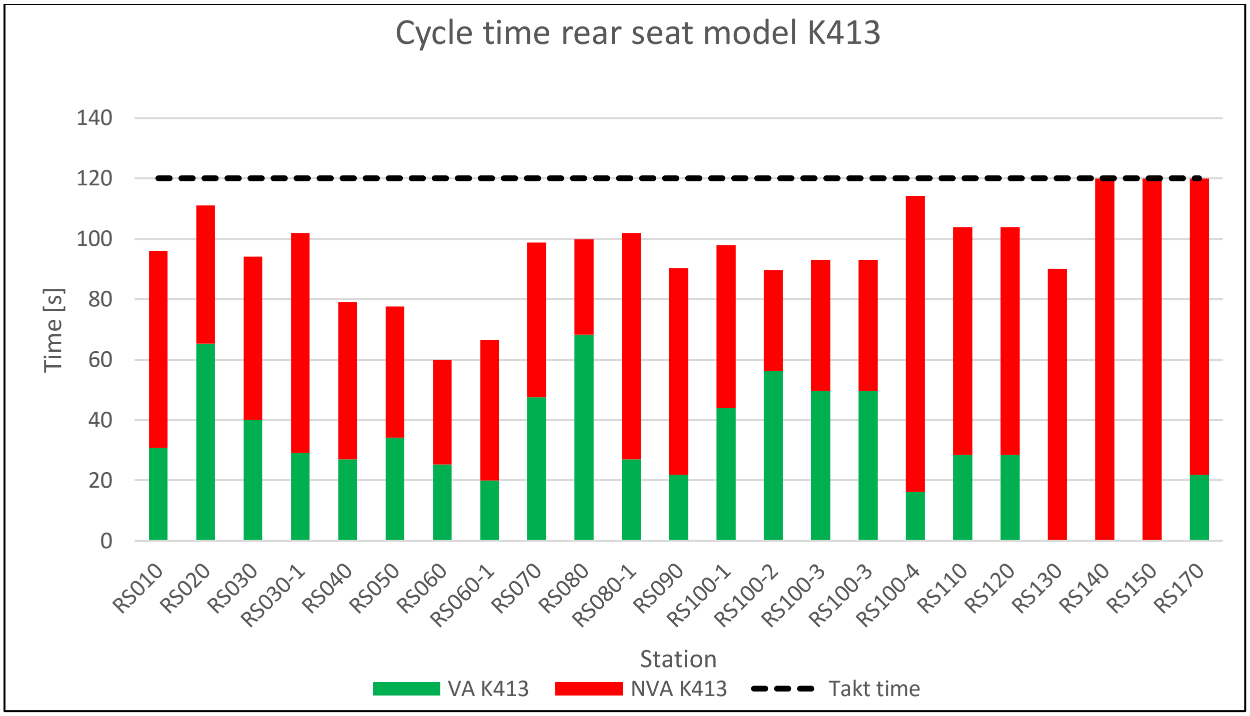

FIGURE 13 CYCLE TIMES FOR EACH STATION ON THE REAR SEAT LINE

The figure shows measured times for the model K413. The line balancing is significantly lower than for the front seat line. The balancing for K413 and L421 on the rear seat line is 80% and 62% respectively. One reason for this is that L421 is based on an older design, whereas K413's design is newer. Major differences of the frame leads to completely different assembly tasks on a majority of the stations. Further, the rear seat line has more non-value added time than the front seat line. The reason for this is mainly because the rear seat line does not have pallets as carriers. Instead, material is transported on a simple conveyor belt and operators on some stations have to move the rear seats from the line to adjacent work tables. The rear seats are also bulky to handle. These operations add to the non-value added time. The problem with underbalanced stations is particularly notable in the first eight stations on the rear seat line, as seen in figure 13. The underbalance is even more significant for L421 and direct observation show operators having to wait for material on these stations.

4.3.2.3 CHECKING FOR QUALITY

Both the front and rear seat line has a quality control station at the end of the line (EPC in the VSM). Incoming material is checked according to a check list and is then sent to either rework or loading. The EPC was planned in the beginning to have 100% quality control when operators were still learning the process and with time, it would be cancelled. However, the EPC is still up and running 18 months after the start-up. First-time-through (FTT) is not measured but interviews and sample measurements showed an FTT of less than 10%. For comparison, JCI in Torslanda has a FTT target of 85% and normally do not fall short of this by more than five percentages. Furthermore, the EPC/rework is also costly. Six operators work in the EPC for front seats and eight operators for rear seats. All checking and rework or corrections is non-value added time. If comparing the time products spend in the EPC/rework area (also time in the inventory) with the assembly time at the main line, the results get clearer. For the front seat line (see figure 11), the assembly time at the main line is 2730 seconds and time in the EPC/rework is

1628 seconds, Thus, from station one to shipping, 37% of the time is spent in the EPC/rework area. The same number for the rear seat is 33%.

4.3.2.4 Excess Inventory

Excessive inventory was common in the factory. This was especially a problem with the inventory between the preassembly and the lines. As seen in the value stream map in figure 11, the inventory levels were 4.7 hours on average, which corresponded to 78% of the total lead time. Only a few low cost parts were preassembled for the front seat, thus merely causing a lack of space and not a decreased liquidity by tying capital in inventory. However, for the rear seat line, many high value parts were preassembled and had even higher inventory levels. For the most expensive part, the rear seat frame, inventory levels were as high as eight hours during repeated measurements. A Kanban system was used with Kanban racks but with an excessive amount of racks. JCI had begun to feel the problems with the inventory levels, mainly because the lack of space. Later in 2015, the foam for cushions and back rests were planned to be made in-house. Thus, space had to be allocated for the large equipment. Also the stock for parts from the EU had to be kept higher due to the low frequency of shipments, adding to the lack of space. See table 1 for an overview of safety stock for groups of material.

Table 1- Material Stock Levels and Deliveries

Part	Safety stock	Delivery frequency
Metal frames	0.5 days	2/day
Foam	2 days	1/day
Plastics	0.5 days	2/day
Trim	2,5 days	1/day
EU parts	1 to 4 weeks	1/week to 1/month

The reason for foam having comparatively high safety stock is because the foam has a 2 day curing time and this time is shared with the supplier (JCI supplier). The logistics department had experienced problems in the start-up with keeping less than 2.5 days safety stock of trims but no investigation as to why had been made.

Other excessive inventory was observed in the EPC area. This was caused by uneven flow through the rework stations. The rework needed was in a range of less than a minute to 45 minutes for a complete rebuild causing an uneven flow with resulting material waiting in inventory. In comparison to inventory levels from the preassembly area, they can be considered small.

4.3.3 Future state & implementations

Given the limited time and resources for this project, only implementations and suggestions for improvements with no major investment cost were considered. Focuses was on reducing personnel and improve flow of material to reduce lead time.

4.3.3.1 Reducing Personnel

The first area with overcapacity and potential to reduce personnel was in the back stuffer stations (FS060). This is 6 parallel stations were the trim is assembled to the back rest. Cycle time was measured to around 300 seconds. Operators at these stations were not working at full speed. JCI

Torslanda has practically the same set-up and methods used but work at full speed at a cycle time of 240 seconds. However, Torslanda personnel are far more experienced and trained and also have some production technology allowing them to work faster. Even so, at JCI Chengdu, reducing one operator would still allow the operators to work at takt time.

A test run was set up during two days were only 5 operators were used. Operators and other personnel were instructed to work as normal and to assure quality at all times. Quality was monitored closely during these two days. The test was a success as no problems with regards to capacity was observed and no quality issues rooted in FS060 was observed. This meant a utilization increase from 81.5% to 90-98% (depending if operator work at full speed or not). This amounts to an annual saving of 58 000 RMB (around 80 000 SEK as of June 2015) in labour costs and without any investment cost.

Another area with need for improvement was the headrest assembly as it was heavily underbalanced with excessive waiting (see figure 12). The headrest assembly was placed adjacent to the line as a preassembly according to figure 14.

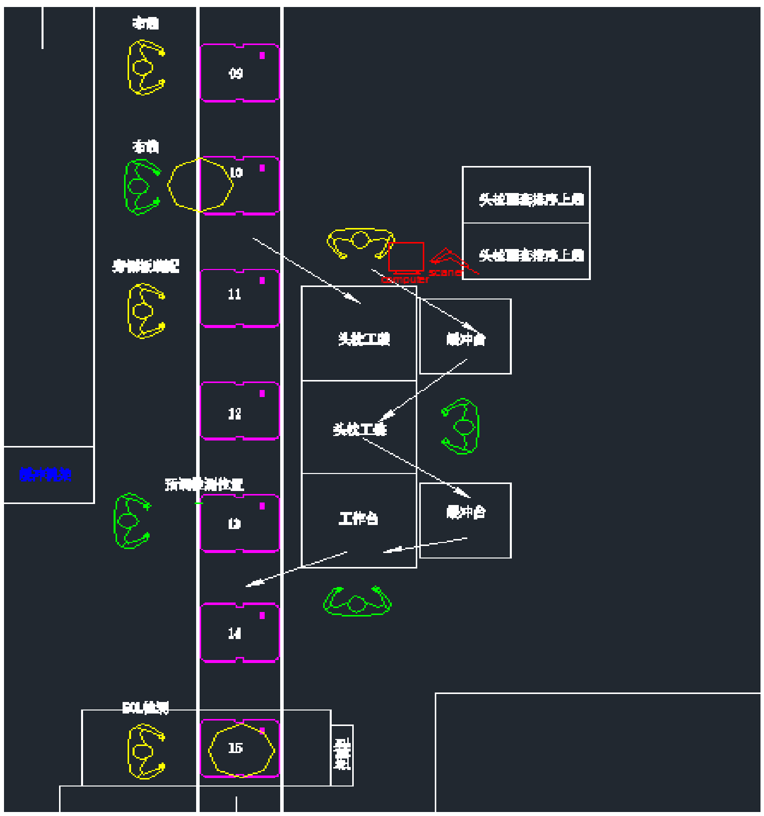

FIGURE 14 OLD LAYOUT HEADREST ASSEMBLY, LINE LEFT IN FIGURE AND HEADREST ASSEMBLY TO THE RIGHT.

The material flows according to the arrows in the figure. The first operator (in top of figure) picks material from a kitting box at the line and performs some assembly tasks. The second operator continues the assembly and the third finishes and walks to the line and places the finished headrest in the kitting box. On station FS180 (the station that follows the head rest assembly), the headrest is mounted on the back rest and a test machine tests if the assembly is made correctly. FS180 has excessive non-value added time when the operator has to wait for the test to finish. Utilization of the headrest assembly as a whole was as low as 52%.

The solution was to reduce the operator at FS180 and put the mounting of the headrest on the last person of the headrest assembly. Also FS180 was made completely automatic with only the headrest test. The layout for the headrest assembly was changed to have a better flow of material and less distance to walk for the operators. The new layout can be seen in figure 15.

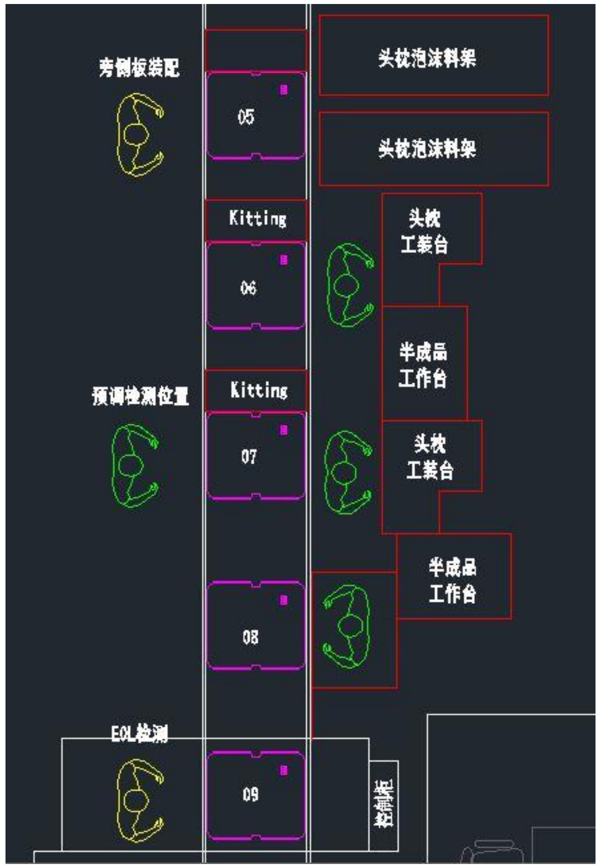

FIGURE 15 NEW HEADREST ASSEMBLY LAYOUT

This new layout enabled a straight flow of material. Stations were moved closer together to eliminate or reduce movements. Also, the whole set up was moved closer to the line to avoid unnecessary movement when picking material from kitting boxes or when assembling the headrest. This solution upped the utilization from 52% to 66% and also reducing one operator at FS180. Also here, the saving amounts to 58 000RMB per annum. The investment cost is negligible (some overtime work for equipment personnel and two sensors at FS180. Also, this solution meant no issues regarding quality of the headrests.

4.3.3.2 MATERIAL FLOW

The VSM analysis revealed some interesting features of JCI's operations, as can be observed in the simplified VSM in figure 11. It shows a total lead time of around six hours. Of this time, 4.7 hours is spent as inventory between the preassembly and the line. This example is for the front seat; however, the situation is the same for the rear seat.

The rear seat frame structure is bulky and the inventory allocates large floor space. Also JCI had problems with their inventory turnover, as it had been flagged by central management to be a top issue to improve. Central management also wants to reduce resources tied up in inventory to increase the working capital.

Today's preassembly is placed far from the rear seat line and the logistics department transport racks back and forth between them. The proposal was to move the whole assembly from today's position (top left corner in figure 16) to where today's inventory is stored (follow arrow in figure 16). By doing so, also simultaneously reduce the inventory to minimum levels. The new position is also adjacent to the start of the rear seat line where the frames are used. There is a Kanban system with Kanban racks, however, there are too many racks. The preassembly always has available racks to fill up with finished rear frames. The output does not correspond to the actual demand and in reality, the system works as a push system.

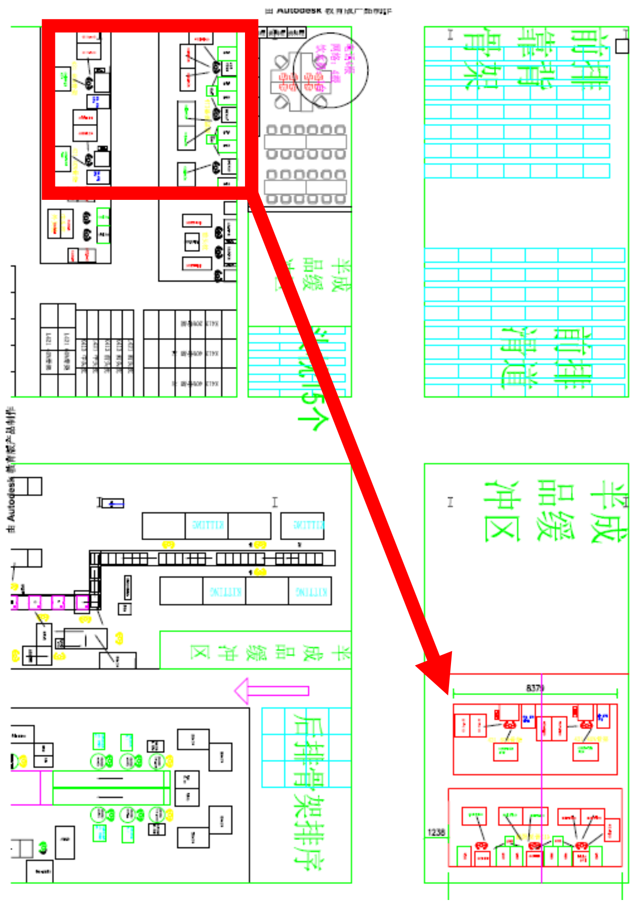

FIGURE 16 REPLACEMENT OF RS FRAME PREASSEMBLY

The preassembly has five stations. Three for K413 and two for L421. Furthermore, three operators work K413 and only one work L421. The measured capacity can be seen in table 2. Historical data, dating 4 months back was used to estimate the demand of each model (hourly demand for both is 30). It showed the relation could be as skewered as 70/30 in any direction (see table 2).

TABLE 2 CAPACITY AND DEMAND FOR L421 AND K413

	L421	K413
Capacity	19/hour	26/hour
Demand	9-21/hour	9-21/hour

If the demand is as high as 70% for L421, then the demand cannot be met with the new set up without excessive inventory. However, this was solved by moving the L421 stations closer to the K413 stations. The proposal also includes turning the L421 stations around so the operators work with their back towards each other. If the demand is temporary increased for either model, the operators can move between them easily to keep up with the demand. This is especially for L421 which has two stations operated by one operator. By moving the preassembly close to the line, operators get a direct view of the actual demand and can adjust accordingly.

Since neither L421, nor K413 can be assembled at the same takt time as the line, some buffer must be kept. This was calculated using the formula (Egerstedt, 1999).

$$K = \frac{d * L * (1+\alpha)}{C} \tag{2}$$

, where K is the number of Kanban racks is, d is the daily demand, L is the lead time for the frame assembly as a ratio of a working day, α is a safety factor, and C is the rack size.

Given a daily demand of 240 sets (30 per hour, 8 hour work day), lead time was measured to 36 minutes, using a safety factor of 10% and the rack size is 12 sets per rack, the minimum number of racks is calculated to;

$$K = \frac{240 * \frac{0.6}{8} * (1 + 0.1)}{12} = 1.65\, racks$$

Thus, two racks should be used in addition to one rack at the preassembly and one rack at the line. A system with two racks was tested during two normal working days and no problems arouse with regards to capacity. Furthermore, the preassembly is not sensitive to disturbances due to the simple layout and simple production equipment. This change has the potential to reduce the lead time from six hours to around two hours. Also, an estimated 100-150 m^2 of floor space saved and total frame inventory reduced by 30% (storage and WIP inventory). This amounts to an increase of the working capital by approximately 30 000 RMB (42 000 SEK as of June 2015). Furthermore, the proposal also eliminates the work by logistics personnel to transport racks back and forth.

Due to time limitations, this proposal could not be implemented but it was presented to senior management leading to the decision to initiate a project to implement in the near future. Also, it was pointed out that the same problems with high levels of inventory exist for all products from the preassembly. Priority to change is for large products with high cost as it will have the greatest impact on floor space and tied up capital where the rear seat frame structure is top priority.

Furthermore, it was proposed to use reusable packaging for bulky incoming material such as metal frames and trim. Today these materials are being shipped in disposable cardboard pallets and boxes. Logistics personnel spend roughly 50% of their time unpacking and the rest of the time is spent on handling the scarp cardboard and pallets. This scrap is later handled by five additional workers who break them down further and load it onto trucks for recycling. It was pointed out that depending on the investment cost for reusable pallets and taken into account future increase in demand that cost reductions can be made by reducing personnel and cost of disposable packaging. Also the investment cost for reusable pallets would lie on Volvo and not JCI. JCI would only see benefits in reduced work for handling scrap. The proposal was pitched in a JCI-Volvo cost reduction workshop and the outcome was the initiation of a project to implement.

5 DISCUSSION

5.1 START-UP PERFORMANCE

The results indeed showed the startup followed a learning curve (inverted) with regards to output. This result is consistent with those of other authors (Baloff 1963, Almgren 1999). Here, case studies of different automotive industries showed a clear learning curve with only differences in slopes of the learning curve (i.e. different times for ramp-up to volume). In accordance with other research, the results here also showed that more complex startups are more resource demanding (time and cost). The time to volume was longer for L421 than for K413, as expected since the L421 startup was more complex. This was due to the novelty of the product and production system was greater for L421. For K413, the production system was known and the product similar to L421. One important aspect that needs to be noted about the capacity performance in the startup is that JCI could produce according to customer demand already after six weeks (i.e. no overtime that was not planned by Volvo). The ramp-up that can be observed in figure 8 is following the demand from Volvo. As JCI is JIT first-tier supplier for a Volvo, capacity is crucial since a failure in delivery would stop Volvo's production, leading to Volvo imposing a substantial fine on JCI. Capacity performance was therefore crucial during the start-up and through interviews, senior managers expressed that the whole organization was highly involved, working concurrently and effectively to allow the success with the start-up with regards to capacity.

Quality performance also showed an inverted learning curve both with regards to quality conformance and the number of rejected parts. Also here a learning curve could be observed during the startup of K413 but with a more rapid time to acceptable quality. However, the extra cost of quality for the startup was high and is still costly at the time of the research. Extra personnel were hired to man the EPC area where checking and corrective measures were taken. This is a direct cost of quality and was only planned for the ramp-up. With quality at the source, the EPC is not needed. JCI in Torslanda have an FTT (first-time-through, i.e. products shipped without any quality corrections or re-work) around 85% and does not need an EPC. Most quality issues that need corrective actions is detected by operators and there is only one control station with one operator, whereas JCI Chengdu has up to eight operators at each line working in the EPC with additional control stations at the lines. This suggests that the startup with regards to quality might not yet be over at JCI Chengdu. Li and Rajagopalan (1996) suggested that the learning curve for non-conforming quality explains the startup performance better than other measures. They also suggest that companies that invest in quality have higher quality and faster learning. What they fail to mention and what is shown by this study is that that all investments does not lead to faster learning. Most investments for quality at JCI were for the EPC which resulted less non-conformance. However, the problems and causes of the poor quality are still in the system. This study suggests that investments should be made at the source of the problems and not for checking and correcting poor quality. Non-conformance might be less but this case can not show any improvements in learning. If investments are made to investigate root cause and solving problems with quality, then a higher learning of the system will be achieved, as suggested by Li and Rajagopalan (1996).

The start-up meant extra costs for JCI. No data could be collected of how many extra man-hours in overtime that were needed to make up for lost capacity. However, interviews with senior managers showed that in these weeks, 30-35 extra man-hours were needed every week, gradually declining to six weeks after the start-up when demand without overtime could be met. Although six weeks can be considered good when comparing to other startups in the automotive industry (Balloff 1963), there was a possibility to have an even more rapid time to volume. In the months previous to SOP, operators were trained in performing assembly tasks. However, they were never trained to assemble at full speed. At the time of SOP, operators were well aware of the assembly tasks but not trained to perform them at takt time which might have caused unnecessary capacity loss during the start-up. To stress the production system as early as possible, even in test series have many advantages. Operators can assemble at takt time, material supply and internal logistics will be tested fully and bottlenecks in the system can be detected. Therefore, it is possible that JCI could have detected and solved some of the problems they had after SOP already during the training of operators.

5.2 Johnson Controls Today

The VSM analysis of JCI's operations today showed wastes in mainly four areas; personnel utilization, excess inventory, checking for quality, and material handling. Regarding the personnel utilization, the line was not very well balanced. The cause of this could be that the station cycle times were based on standard times. These times might not have been accurate after maximum capacity was reached even though the lines were designed to be well balanced and empirical evidence showed that many stations were underbalanced and more effort could have been put into update these times with time studies to improve productivity already at an early stage.

Excess inventory was commonly observed and the most wasteful inventory was observed in the inventory between the preassembly and line. A majority of the total lead time for material from pre-assembly out to shipping was spent in this inventory. Not only smaller parts from the preassembly, but also the high value parts were waiting in this inventory (rear seat frames). It also showed that the high value parts were also those which had highest inventory levels. This caused more than one problem at JCI. The time material waited in the inventory was the largest contributor to the total lead time. A considerable amount of space is allocated to this inventory which became a problem during the study. JCI moved their foam line from another facility to the Chengdu facility. This new line requires ¼ of the total floor space which meant keeping low inventory levels for increased floor space became increasingly important. On top of this, by reducing the inventory levels from the preassembly, JCI could free a considerable amount of working capital previously locked in inventory. This would also increase the inventory turnover which is a performance metric important for central management in JCI.

The checking of quality, especially in the EPC is a major waste at JCI today. Besides material in inventory, products spend most time in the EPC. The checking for quality is per definition a waste since it does not add value to the customer. Furthermore, if operators are able to assemble with acceptable quality already at the line, the EPC is redundant. The quality at JCI is dependent on skilled operators with know-how of how to build the seats with quality. In post start-up JCI plants like the Torslanda plant, the processes and methods used are basically the same with only minor differences. Operators often have around 5 years of experience of working with automotive seating and have great skill in how to build for quality. This is lacking at JCI Chengdu. Most operators have worked less than one year and interviews showed it was hard for

JCI to retain personnel and lower personnel turnover. Managers at JCI expressed their concern of the high personnel turnover and the effect it had on the quality. High personnel turnover is a problem in China and this phenomenon is brought up by several researchers (Khatari et.al 2001, Jiang et.al. 2009). Managers also mentioned that the labor community in the industrial area that JCI is placed in, is well aware of other employers' salaries. Poaching is therefore common where nearby companies offer a slightly higher salary. This might be the reason JCI struggle with quality or more specifically, the cost of quality. It is possible that JCI's quality performance could have been better and with less cost since other research and interviews suggests so. And as mentioned, JCI's products demand skilled workers to perform quality critical work tasks. For this reason, it is a probable reason for JCI still having the EPC 18 months after start-up. JCI had some problems with quality of incoming material during the start-up and this was the reason for having personnel inspecting incoming material. This personnel was still inspecting incoming material at the time of this study. There was no documentation of the quality performance from suppliers. Since suppliers also have an initial learning curve with the new product, it is likely that quality is better today than it was during the start-up. Since JCI checking of incoming material is a waste, it should be eliminated. Other wasteful activities observed in the logistics department were the unpacking of material onto Kanban racks. This was observed for many types of material. Even common parts were unpacked and placed in Kanban racks. Containers for common parts were neither large, nor bulky which allows them to be transported straight from storage to the line without unpacking. By doing so, this would eliminate unnecessary work.

To summarize the results, JCI's start-up performance showed to follow a learning curve with regards to capacity and quality. These results showed to be consistent with those of other research (Baloff, Almgren). The analysis of JCI performance today showed that some of the problems today could have been avoided from the start-up, especially reduced WIP and personnel utilization. A result that differed from other research made was the source and type of disturbance. Most researchers found disturbances in product concept with late engineering changes. This was never a problem at JCI. The plant was new for JCI but the products were still of older design and already manufactured at other sites so no major engineering changes were needed. Other research has also shown start-up companies to have a lot of disturbances with production technology, something that was not a large problem at JCI. JCI uses standardized equipment and lines for all their seating operations which allowed for this. Supply of material was also not a major problem for JCI during the start-up which is something commonly found in other start-ups. JCI managed the team of engineers and managers to work effectively with the start-up and had an excellent information flow as it is a success factor in a start-up (Fjällström et.al). In Fjällströms research the largest success factor was to use experienced managers during the start-up. JCI had experienced expats managing the start-up which could be one reason for its success. Furthermore, level of skill seemed to be the most influencing factor for JCI's start-up. This result has not been found in other research. It is likely that this is caused by the Chinese labor market. Poor migrant workers, motivated with monetary incentives show a high likelihood of change job for even a slight salary increase. This problem was found at JCI which had problems in retaining personnel and keep a low personnel turnover. This affected the quality during the start-up and also today with extra cost for rework.

5.3 METHODOLOGY

The methods used showed to answer the research questions well. Using a single case study research methodology according to Yin (2014) with quantitative and qualitative data collection gave a clear view of JCI's start-up performance. Collecting quantitative data from JCI, combined with qualitative data through interviews showed to be effective and results showed to be consistent with other research. Using VSM to analyze JCI in real time gave necessary results for this case study; however, the data collection for the method was tedious and resulted in more information than needed.

It should be discussed whether the chosen method allows the results to be generalized for other similar industries (i.e. JIT first-tier suppliers in the automotive industry). Most previous research is conducted at car manufacturers so this study adds to the field by including a first tier supplier in the automotive industry. It also compares start-up performance with post start-up performance which to the author's knowledge, has not been done before. Future research could include a broader study with multiple cases to add certainty and be able to generalize the results.

6 CONCLUSION

The purpose of this study was to analyze JCI's operations during the start-up and the current state with regards to performance and how disturbances affected performance. Also, the purpose of analyzing both was to see if there was any connection between today's disturbances and problems with those of the start-up. With knowledge of this, the purpose was to investigate whether problems at JCI today could have been avoided already during the start-up and also propose improvements and/or implementation. In light of this purpose, a few research questions were to be answered. These will be answered in this chapter with brief answers to summarize the findings from the study.

1. *What does previous research tell us about the connection between present disturbances and the start-up phase?*
   Most previous research of start-ups in the automotive industry show a set of disturbances commonly felt. Sources of these disturbances are either from product design, materials flow, production technology, and work organization. These sources can cause many problems, engineering changes in a late stage, poor quality of material, machine quality performance and capacity, and level of skill of operators can affect both cycle time and quality. Most researchers point out that if these sources are not dealt with as early as possible, the problems are likely to continue to cause disturbances. An extreme case is machine intensive process industry where full capacity often is not reached before several years after SOP. To the author's knowledge, there's no research connecting disturbances during post start-up with those during start-up. However, research show that problems not dealt with will remain and that inefficient solutions will induce extra cost. Expected disturbances at JCI were therefore those commonly observed during start-up but also inefficiencies caused by poor solutions to start-up disturbances.

2. *What disturbances did JCI have during start-up and why were they present?*
   There were mainly 3 reasons for lost capacity; production technology, materials supply, and level of skill of personnel. Minor stoppages caused by production equipment were present. These stoppages were minor and commonly observed during start-ups. All machines and systems have to be tuned in before they can work reliably. Materials supply was good with regards to delivery performance; however, the quality of incoming material was poor. This caused a lot of rework and lost capacity. The reason for this can be many but it is likely that suppliers also experienced a start-up phase with less than acceptable quality. Furthermore, skill of personnel caused most capacity loss and poor quality during the start-up. Previous research showed that these types of disturbances are common but at JCI, the level of skill was the dominant source of disturbances. This phenomenon has not been found in other research. The organization's failure to train operators at full speed prior to the start-up was the most likely cause of this. Operators experienced a "shock" at SOP as they had never assembled at intended speed.

3. *How were these disturbances solved?*
   The production technology was tuned in and adjusted during the first weeks after SOP and did not cause any capacity loss that could not be made up for during normal working

time. JCI introduced inspection of incoming material to assure quality and to avoid any rework caused by poor quality of parts. Operators was not trained any further more than during normal working hours but overtime was extensive during the first six weeks of the start-up. Poor quality caused by operators was mainly solved by adding personnel to the EPC and rework area where quality is checked and corrections/ re-work is made.

4. *What disturbances does JCI have today?*
   Waste analysis through VSM showed wastes in mainly 4 areas; Personnel utilization, excess inventory, checking for quality, and material handling. Low utilization of personnel was observed in several places, causing waste when waiting for material. Excessive inventory was observed, especially between the line and preassembly. The preassembly does not work with the same takt time as the line, since many of the operations take a lot longer or shorter time. Operators move between different stations with different tasks. Therefore there is an uneven flow from the preassembly, thus causing an increase in inventory. Problems with quality were caused mainly by the low level of skill of operators (to some extent also quality of incoming material). This was due to the lack of training at full speed prior to start-up and then also due to a high personnel turnover. It is likely that the nature of the Chinese labor market caused a high personnel turnover, where poor migrant workers, mostly motivated with high salaries are poached from nearby factories offering a slightly higher salary.

5. *Has the start-up phase had an effect on the disturbances JCI is experiencing today? If yes, how has it had an effect?*
   The personnel utilization was low on some of the stations at the line. During the start-up, more personnel had to be added to keep up with the demand. This was during a time when operators' level of skill was low and they had to use most of the takt time for assembly. At the time of the study, operators were more experienced and could finish assembly tasks well below takt time, leading to today's underbalance. Thus, disturbances during the start-up when operators fail to assembly on time has likely led to today's situation. Disturbances in the preassembly area during the start-up is one cause of today's high inventory levels. Interviews showed that during the start-up, there were problems with capacity in the preassembly. The solution was to focus operators to work multiple stations with batches and by doing so, increase the inventory. Safety stock for some material is kept high for compared to others. Delivery reliability for trim and foam was poor during the start-up as suppliers also were experiencing common start-up disturbances. However, the safety stock has not been updated and it is likely that the suppliers' delivery performance has increased.
   Disturbances during the start-up caused by poor quality from suppliers made JCI hire inspection personnel to the logistics department. Observations made showed that very few parts were rejected in the inspection and parts with poor quality could have been detected by operators at the line. During the start-up, supplier's quality was poor but it has since then improved making the inspection obsolete and wasteful. The largest disturbance during the start-up was poor quality. It was solved with the EPC and since then, product conformance and rejected products are on acceptable levels. Many of the causes of poor quality were still in the system at the time of the study. Many of the causes could be traced to operators' ability to assemble with acceptable quality, especially for

the assembling of the trim. Quality improvements have therefore been made in wrong areas instead of at the source of the poor quality. Even if quality metrics show green numbers, the problems are still there and are likely to continue to exist if not resources are focused at the source of the quality problems. Also, through interviews with operators it came clear that there was a poor attitude to personal performance with regards to quality. Operators were well aware that the EPC would correct their mistakes.

6. *How can JCI's current operations be improved?*
   The utilization of personnel was shown to be low at JCI. During the project, some implementations reduced two operators with just layout changes and better balancing. There are more opportunities to reduce personnel at JCI today, especially when considering the customer is only paying for the cost of 75 operators instead of today's around 150. JCI's BBP show that other plants worldwide with similar operations and complexity can be run with fewer operators. JCI has a lot of extra personnel in the EPC which is one of the main causes except from low utilization. JCI has a long way to go before the EPC can be removed. Personnel turnover is a problem as JCI needs skilled operators to keep acceptable quality. JCI should therefore work with personnel retention and keep the work place attractive with monetary means as well as other benefits.
   Furthermore, JCI has problems with too much inventory and inventory turnover which was shown to be caused by the excessive inventory between the preassembly and the line. A proposal to change this was presented with relocation closer to the line and heavily reduce the inventory. By doing this with most or all material from the preassembly could have a huge impact in available floor space, inventory turnover and working capital.

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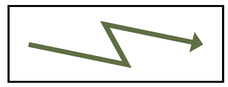
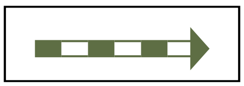
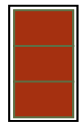
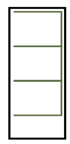
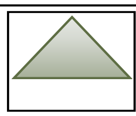
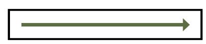
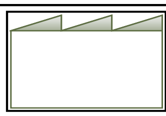
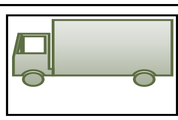
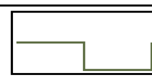
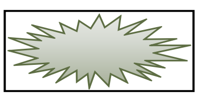
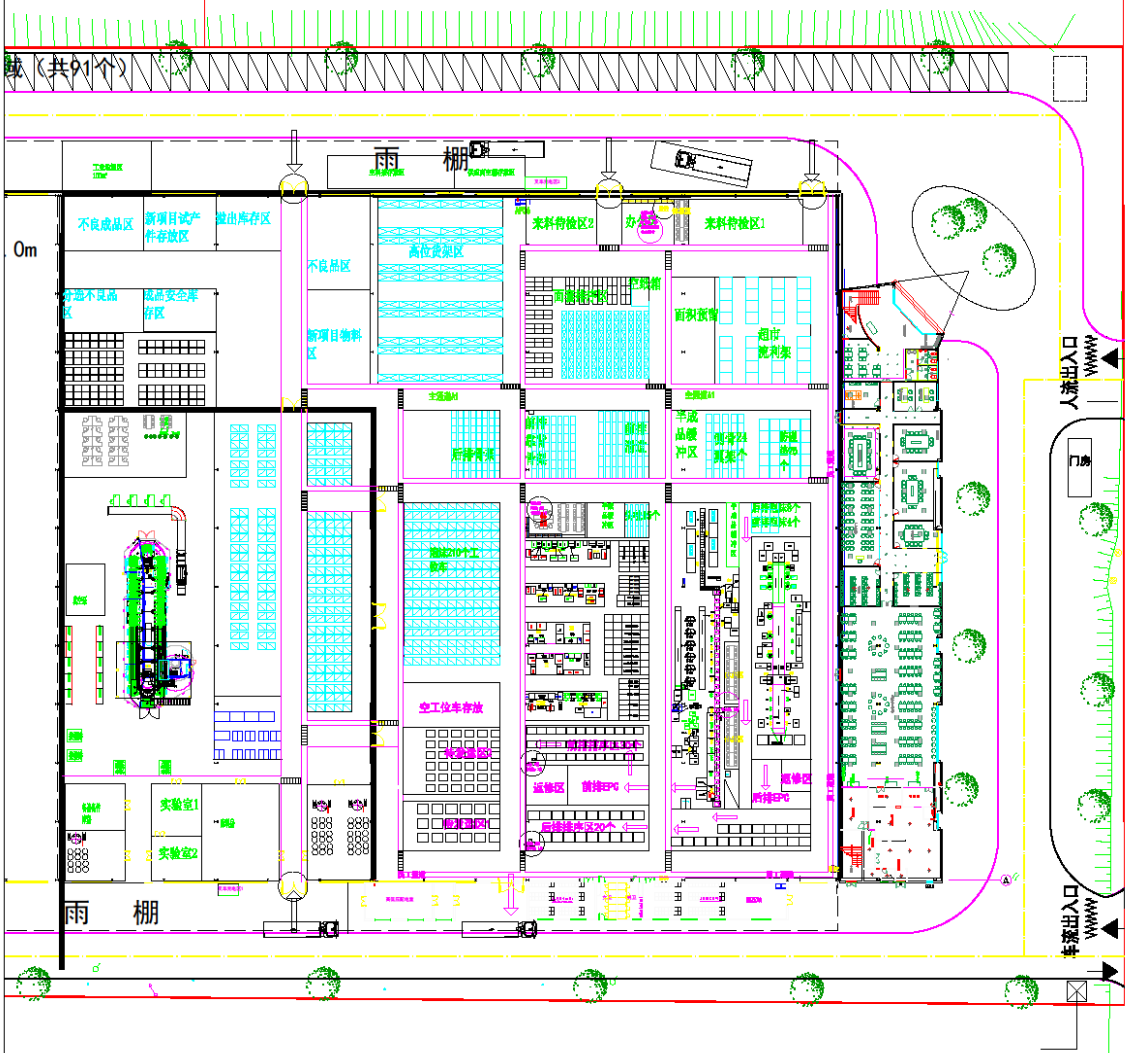
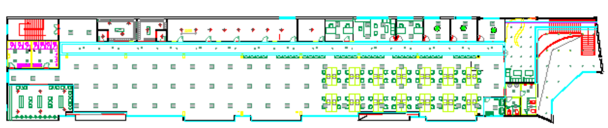
APPENDICES

APPENDIX A – VSM SYMBOLS

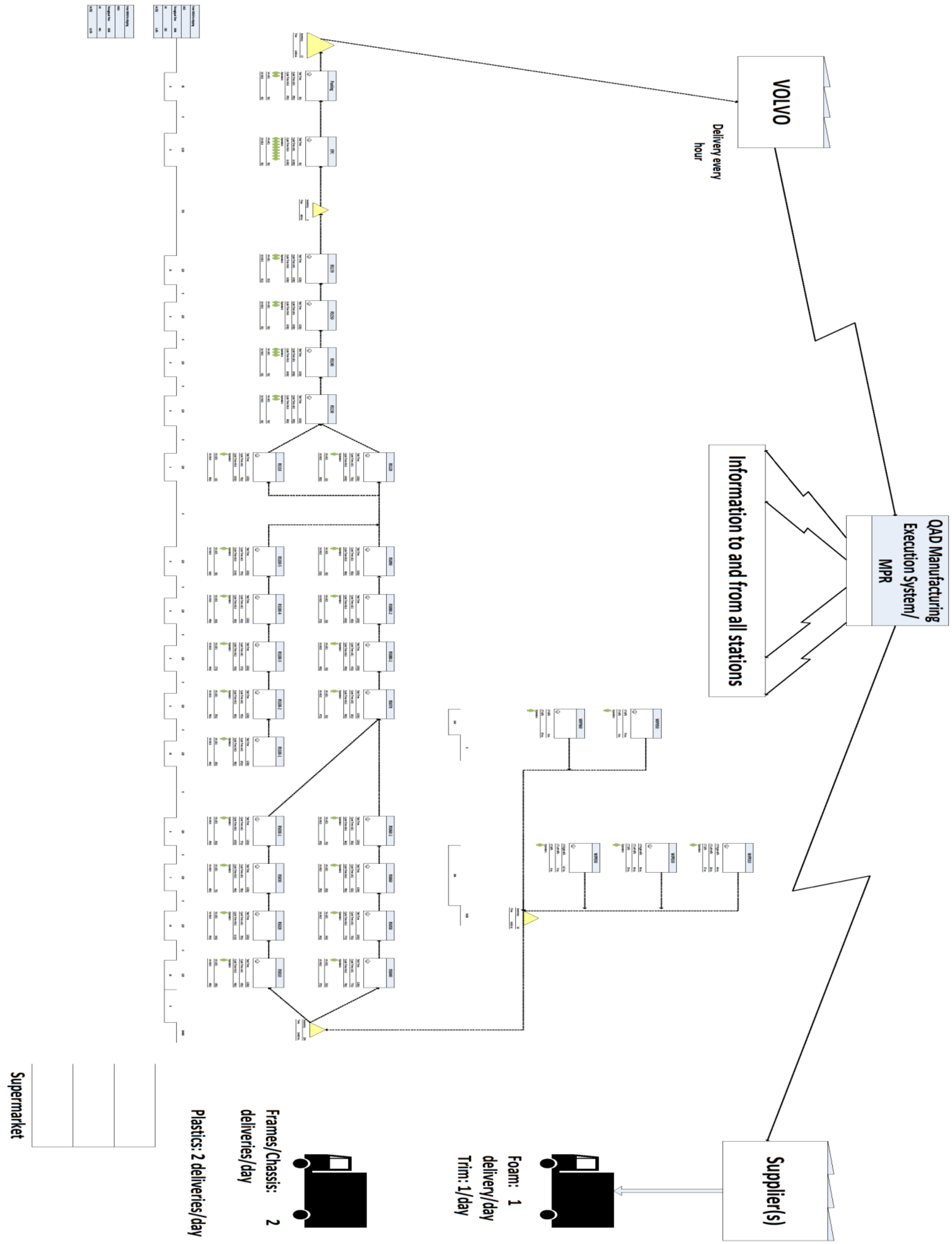
VSM Symbols			
Symbol	**Description**	Symbol	Description
	Process		Electronic information
	Push arrow		Safety stock
	Shipment arrow		Supermarket
	Production Control		Pull arrow
	Inventory		Manual information
	Customer/Supplier		Physical pull
	Shipment truck		Timeline segment
	Kaizen burst		

APPENDIX B – PLANT LAYOUT

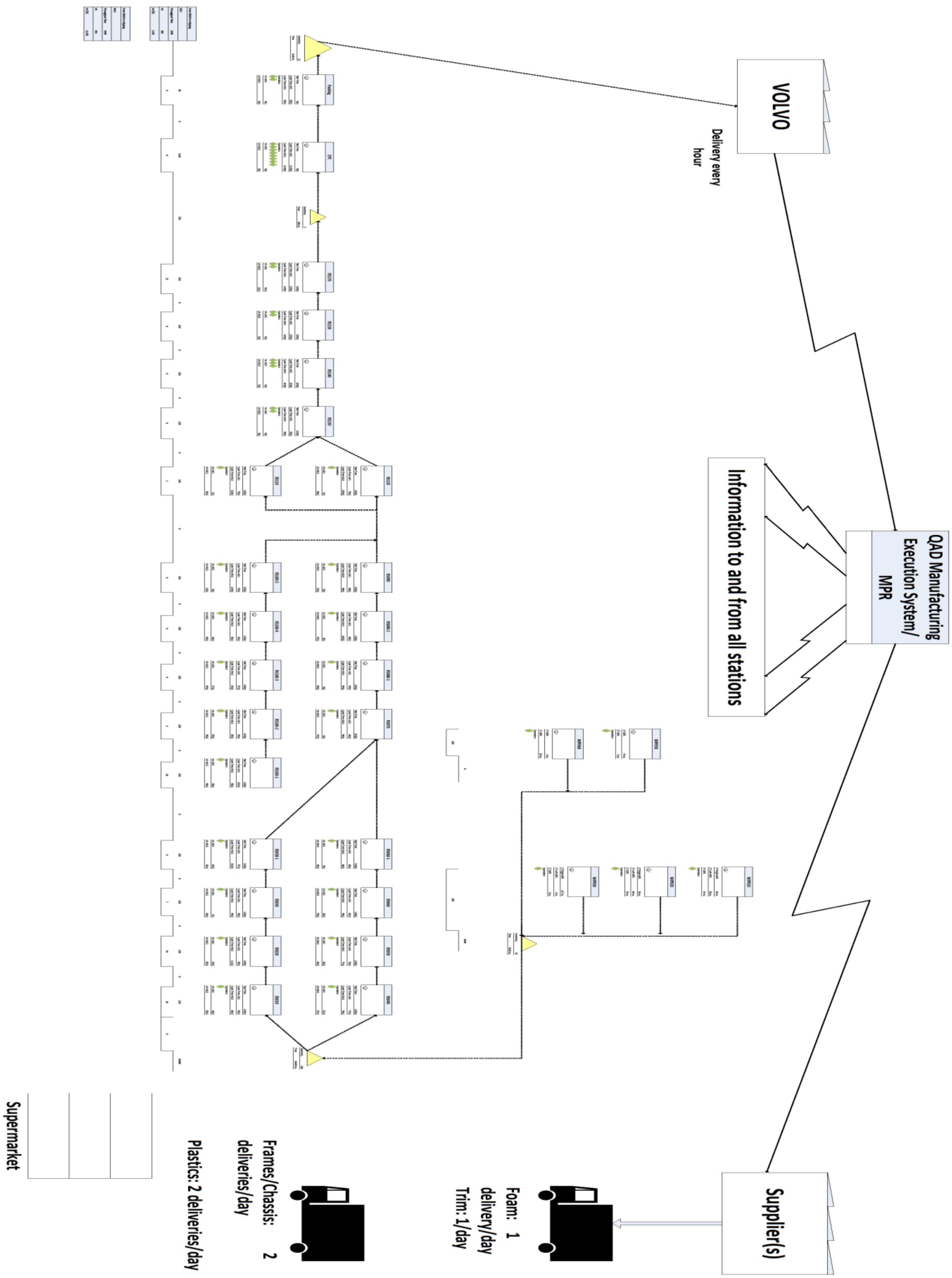



二楼平面布局图

APPENDIX C – VSM FRONT SEAT



APPENDIX D – VSM REAR SEAT



APPENDIX E – REAR SEAT FRAME STRUCTURE ASSEMBLY