THE IMPACT OF JUST-IN-SEQUENCE DELIVERIES TO THE WIDER SUPPLY CHAIN

PETER RAKOVAN

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Téma práce:	**Dopad "Just-in-Sequence" dodávek na širší dodavatelský řetězec**

Zásady pro vypracování:

Úvod

Definujte cíle práce a použité metody zpracování práce.

I. Teoretická část

- **Zpracujte literárni rešerši vztahujíci se k problematice Just-in-Sequence dodávek se zaměřením na automobilový průmysl.**

II. Praktická část

- **Popište a analyzujte současný stav Just-in-Sequence dodávek ve dodavatelskem řetězci firmy TI-HANIL.**
- **Vytvořte mapu hodnotového toku stávajíciho dodavatelského řetězce.**
- **Navrhněte doporučení pro zlepšení stávajíciho dodavatelského řetězce.**

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Fakulta managementu a ekonomiky
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Abstract

Automotive industry has gone through many changes over the last decades. Production managers have been under constant pressure to increase efficiency of the production plants. In the 1990s implementation of the Japanese model of a lean manufacturing has become unnecessary for the automotive industry in Europe, in order to stay competitive in the global market. Just-in-time deliveries have been fundamental base stone of the lean manufacturing. Furthermore, in the 2000s customization has become a key competitive advantage. To cope with large complexity of customized production while keeping the cost low, manufacturers started to seek for so called mass customization. Modular production has been proven to be able to deal with a customized production while utilize on the aspects of the lean manufacturing. To enhance the above mentioned changes towards the customized production, manufacturers started to implement just-in-sequence. Just-in-sequence is a stockless form of supply based on just-in-time philosophy. It enables stockless supply to sequenced productions, which just-in-time could not deal with. Just-in-sequence deliveries are synchronized with the sequence of the assembly line. That way there is no need for extra inventory that would have to be stored nearby the assembly line. Despite the fact that just-in-sequence has become crucial order winner for many automotive suppliers and has been implemented to some extend by the most of the car manufacturers in Europe, there is lack of empirical studies carried out. This fact is even enhanced by the variety of possible modification of the just-in-sequence deliveries. Therefore, this report intends to enlarge already gained practical knowledge in this field. Another question that has not been answered by the available literature in this field is whether this form of deliveries required by car manufacturers has an impact on the wider supply chain. This report is therefore taking a larger picture of a supply chain. Using value stream mapping, impacts of just-in-sequence on inventory levels, organization of production and cycle times could be analysed in an original equipment manufacturer (OEM), tier 1 supplier and tier 2 supplier. It is clear that the tier 1 supplier is directly affected by just in sequence deliveries. However, it was concluded that there is

no evidence of effects further upstream the supply chain in the measured supply chain.

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1. Introduction

1.1. Background to the research

In the late 1980s and early 1990s automotive industry has transformed to the new model of the global approach with the emerging markets seen as a opportunity for leading-edge productions. Also manufacturing process itself started to change. Lean manufacturing as a good case practice from Japan started to shape new production plants. Just-in-time deliveries have been crucial part of the lean manufacturing. However, implementation of this form of deliveries was conditional to abilities of the suppliers. To support just-in-time, European market started to shift towards built-to-order. All of the changes has had a huge impact on the whole environment of automotive suppliers as this industry is typical with a large proportion of outsourcing.

Furthermore, in the 2000s customization has become a crucial competitive advantage. Complexity of productions increased dramatically. To deal with the complexity while keeping the costs low, the automotive industry started to implement so called mass customization. For car manufactures customized production resulted in further outsourcing of processes that used to be done at the assembly line and formation of supplier parks to increase proximity of its sensitively chosen suppliers.

During all of the above mentioned, in the 2000s just-in-sequence deliveries started to make its way to the industry to enhance the changes. It is a stockless form of supply based on a just-in-time philosophy. Suppliers are sequencing the products according to the production, so that there is no extra stock required at the assembly line. However, there are many challenges. Trust built between suppliers is essential as this form of supply requires high quality standards. As well as just-in-sequence offers a big potential for improving efficiency, faults in deliveries are fatal and can cause large losses.

This thesis will provide a case study of a supply chain that uses just-in-sequence. Purpose is to enlarge already gained knowledge in this field as well as analyse impact of just-in-sequence deliveries used by the car manufacturer further upstream the supply chain.

1.2. Justification of the study

Despite the importance that just-in-sequence has for the current customized production of the automotive industry, there has not been enough research published regarding this topic. For example, in comparison with just-in-time there is significantly less literature and case studies available. This is even enhanced by the fact, that there are different logistic and production structures that are used to deliver just-in-sequence. Therefore, this research offers a case study that enlarges empirical knowledge already gained in this field.

Even though just-in-sequence has been known for several decades, it is still very relevant for many suppliers. It requires long term strategic change to create ability for this form of supplies. In this research there are evidences that some car manufacturers in Europe started to develop this types of deliveries in 2010s.

Furthermore, proportion of deliveries that are supplied just-in-sequence has been growing. From early 2000s when only about 40% of parts where delivered just-in-sequence, in 2013 around 80% of the parts were delivered using this method. It can be expected that the proportion will even increase in the future which will require new suppliers to adapt this technique.

1.3. Aim of the research

The aim of this research is to provide a practical example of an embedded case study to enhance already gained knowledge in the field of just-in-sequence deliveries. Furthermore, all of the research already carried out focused on an original equipment manufacturer and its tier 1 supplier. To address this research gab, this report will give an overall picture of a multiple facility supply chain and it will try to examine impacts of just-in-sequence deliveries to the wider supply chain rather than just to the first tier of automotive supply chain.

2. Literature review

2.1. Introduction

Literature is a published context of research that has already been carried out. It can have different forms such as journals, articles, books, reports and so on (Quinlan, 2011). This part of the thesis is a review of literature that is currently available and is relevant for the topic of this thesis.

The aim of this literature review is to get an understanding of current state of literature and to validate the research´s topic. This review shall not just describe available literature and authors but it shall also include a critical evaluation of those studies (Easterby-Smith, Thorpe & Jackson, 2008).

The first part of the literature review talks about the development of the European automotive industry from the late 1980s until today. Rapid increase in customization and high competitiveness of automotive industry has brought just-in-sequence as a delivery system of the late 2000s. Therefore, one sub-chapter of this review will talk about just-in-sequence deliveries more in depth. Furthermore, the last chapter will prove that the topic of this thesis is valid and up to date.

2.2. Automotive industry development and contemporary practices

The automotive industry in Europe has been experiencing a fast grow over the last few decades. While Western Europe has been stagnating, Central Europe (Czech Republic, Hungary, Poland, Slovakia and Slovenia) has grown from 1.6 million passenger cars in 1994 to 5 million cars in 2008 (Radosevic & Rozeik, 2005).The fast grow has been generated mainly by foreign investments. In the year 2006 two manufacturing plants of KIA and Hyundai started to operate in Slovakia and Czech Republic with production about 800 000 passenger cars per year. (Kia.sk, 2014; Hyundai.cz, 2014)

In the late 1980s and 1990s the world’s automotive industry has transited from an old domestic model to a newer and global model. The old model was focussing on exporting from the domestic country and using emerging markets as dumping yard for old models. On the other hand after the transition towards the new model´s competition was based on global production and emerging markets were seen as location for building leading-edge productions. Car manufacturers started forming joint ventures and sharing costs for the development of similar modules. For example VW, Audi and Škoda have created a platform where they share the same car parts and modules for their products such as engines, chassis and so on. (Radosevic & Rozeik, 2005).

In the 1980s and early 1990s European automotive industry processes also started to change by influence from Japan. To cope with cost pressure and high competition car manufacturers started to implement a lean model of car manufacturing. Just-in-time deliveries are a very important component of lean production. Just-in-time means that an exact quantity of defect free raw materials, parts and subassemblies are delivered to the place where they are needed at the exact time when they are needed (Ōno, 1988). To implement just-in-time car manufacturers must have selected a few suppliers with a long-term partnership to ensure high delivery dependency, high standard of shared information system for quick and reliable communication and high quality of incoming parts as quality checks of delivered products are limited (Thun, Marble& Camargos, 2007).

Just-in-time deliveries were also conditional to built-to-order or precise forecasts. European market started to shift towards built-to-order which is particularly demanding for short lead times to satisfy customer´s expectations (Turnbull, Oliver & Wilkinson, 1992; Larsson, 2002). Built-to-order production can be characterized as a pull system where orders trigger the production of all the parts. It demands a flexible supply chain which is working synergistically to the supply specific car of a specific customer within reasonable time and cost. The main advantages are prevention of forecast inaccuracies which can lead to an obsolete stock and generally lower inventory of finished goods. However, keeping the lead time short for the customers is a big challenge. It is not the production process itself that is the main challenge of meeting customer lead time expectations. It usually does not take more than one day to assemble a car which is a small proportion of the overall lead time which is several months. But the synchronization of entities in the supply chain and knowledge of managers is crucial (Hart, 2005).

Another reason for built-to-order production was customization. In the 2000s satisfaction of individual customer demands started to be crucial for gaining competitive advantage in the automotive industry (Thun, Marble& Camargos, 2007). Therefore customers can choose from a long list of individual options. Such options include tyres, engines, colours, and the interior trim and so on. This leads to an enormous number of model variants. For example in AUDI, on average, only 1.5 cars per year leave the production line with the exactly same configuration as there are billions of variant combinations (Thun, Marble& Camargos, 2007; Berlit, Dorndorf& Zimmermann, 2008). European car manufacturers started to seek for lowering inventory and lead times while increasing customization by shifting towards mass customization. Mass customization represents the concept of production with the objective to both use high variety and responsiveness of customized production and utilize efficiency of lean mass production (Blecker, Abdelkafi, Kaluza & Kreutler, 2004).

The effect of this shift has been huge to the wider supply chain due to the fact, that lean car manufacturing is specific by large proportion of bought-outs. In the early 1990 up to 60% of the entire car production cost was derived from tier 1st suppliers from which parts were bought. This proportion has been increasing as the European automotive industry was following good case practises from the successful Japan automotive industry where the revolutionary idea of lean production has been developed in the 1950s (Thun, Marble& Camargos, 2007). In Japan bought-outs represented 70-75% of total car production costs. It means that only 25% of the value is gained in the last assembly process by car manufacturers. This would have led to a tremendous amount of suppliers without further changes in car manufacturer and supplier relationship (Turnbull, Oliver & Wilkinson, 1992; Larsson, 2002). According to Japanese model, to cope with large number of suppliers, tier 1 suppliers formed affiliated groups. Therefore, even though there are many suppliers, relationships between car manufacturers and tier 1 suppliers are kept simple. Thanks to that, quality standards together with product design are united across the suppliers (Turnbull, Oliver & Wilkinson, 1992).

However, the outsourcing of assembly activities varies throughout the industry even within the same country. For example AUDI and SUZUKI have their production plants in Hungary. While AUDI has been outsourcing most of its production activities some of SUZUKI´s suppliers just could not meet required standards. As a result in the late 2000s, SUZUKI reversely in-sourced the production of some parts in-house. This was mainly caused by SUZUKI´s underdeveloped relationship with its suppliers. Therefore, the maturity of the market and relationships between individual companies are constraints for adapting the Japanese models of lean car manufacturing and just-in-time deliveries. (Demeter, Gelei & Jenei, 2006)

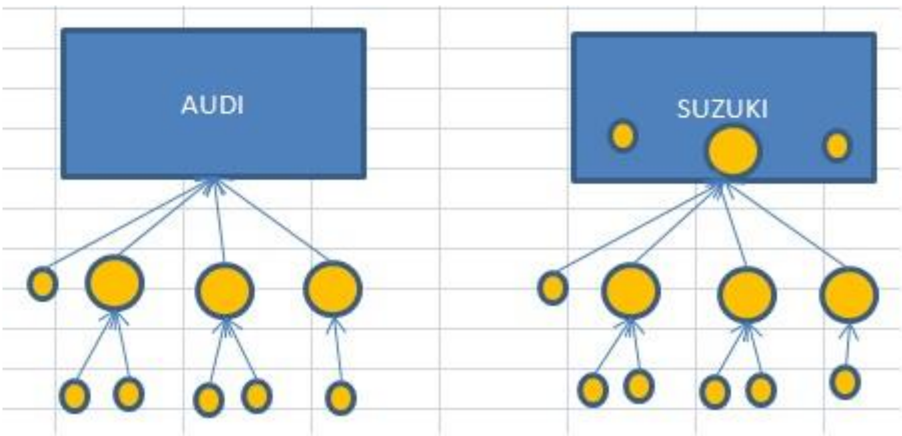


Figure 2-1 AUDI vs. SUZUKI supply chain design in Hungary (Demeter, Gelei & Jenei, 2006)

To meet individual customer demands in short lead times a decoupling point is also an important aspect for car manufacturers. According to Mason-Jones, Naylor & Towill (2000) there are three types of manufacturers as illustrated on the figure below.

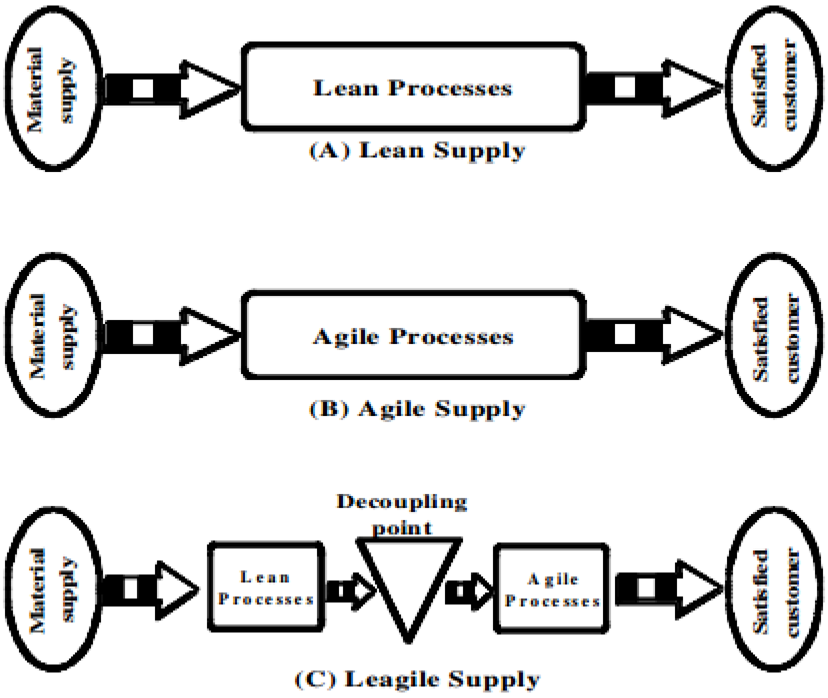


Figure 2-2 Decoupling point (Mason-Jones, Naylor & Towill, 2000)

Lean processes aim to eliminate all waste, included time, and to maintain a levelled production. Costs are the main driver. An example of a product manufactured by lean processes is milk. The demand is stable and the product itself does not change over time. On the other hand agile processes try to utilize on quick response to the volatile market demand. It tries to use market knowledge to exploit actual and profitable opportunities. Such an example is the fashion industry with volatile demand and large amount of product designs to match individual customer demands. The third example, leagile manufacturing, combines paradigms of both lean and agile processes to best suit for volatile demands downstream from decoupling point while providing levelled production upstream (Mason-Jones, Naylor & Towill, 2000). An example of leagile production is the automotive industry. If the decoupling point is moved downstream the supply chain lead times are shorter. However, it requires lowering complexity of upstream products to level the production.

The emphasis on pushing the decoupling point downstream the supply chain has led to so called “modular production”. Modular production distinguishes between the car as totality or as a product that is built up of modules. These modules are designed and manufactured by the affiliated groups, without any dependence to other modules (Larsson, 2002). This way, each affiliated group is responsible for each module and the car manufacturer is assembling a few dozens of modules rather than hundreds of car parts. Such an example of modular production can be seen in MCC factory in France. This factory is producing SMART cars by assembling 8 modules(Johnston, 2003). SMART cars proved that modular manufacturing can be implemented for the production of highly customized products.

Just-in-time deliveries and modular production have bounded car manufacturers and suppliers together and stimulated formation of supplier parks. The main advantage of supplier parks is the proximity of suppliers to the assembly line which is essential for just-in-time deliveries. There are several supplier parks in Europe as for example in Germany, Belgium, Spain, Italy, UK, Portugal, France, Sweden, Poland, Slovakia, and Czech Republic. However each operates differently. Volvo in Sweden built its supplier park to improve proximity of suppliers that deliver products that are:

- Voluminous,
- require large storage space,
- high transport cost per unit and
- large number of variants.

The main purpose of the car park was to prepare for sequenced deliveries from the suppliers. The SAAB car park was specific because it had no suppliers in it. It worked as a hub warehouse with the function of sequencing the most time dependent deliveries. This warehouse is managed by a third party logistics company. Audi built a logistics centre and a supplier park at one place. The main purpose of the supplier park was to react on increasing demands for sequenced deliveries. In contrast with SAAB, all of the companies in the park take part in sequencing, delivery and final assembly of the assembly line. SEAT in Spain has also built its suppliers park as a reaction to the vision of sequenced deliveries. Here, suppliers are located in the park where they assemble their products but sequencing is administrated by a third party logistics company. Ford built a supplier park in Germany with more objectives. The outsourcing of some of the assemble processes improved the overall quality which the company had been battling with. By outsourcing the production to its suppliers Ford also decreased the amount of employees and gained labour flexibility. Another objective was similarly to all the other manufacturers. It was a preparation for just-in-sequence deliveries. As it is obvious from above mentioned common reason for establishment of supplier parks is upcoming method of sequenced deliveries (Larsson, 2002).

2.3. Just-in-Sequence

Despite the fact that just-in-time has the potential to decrease inventory dramatically it fails to cope with huge variety of car modifications as mentioned earlier (Thun, Marble& Camargos. 2007). In early 2000s just-in-time deliveries were enhances by sequenced just-in-time deliveries or also called “just-in-sequence” deliveries. Just-in-sequence deliveries require suppliers to deliver unique products in the sequence and synchronized with the assembly line of the car manufacturer (Larsson, 2002).

Just-in-sequence is a stockless form of supply, based on just-in-time philosophy. When using just-in-sequence receiving floor is completely eliminated. Required parts are delivered in the right sequence directly to the place of final assembly at the time when they are needed. Especially for parts with a large amount of variants, which are typical for the automotive industry, inventory is decreased dramatically (Thun, Marble& Camargos. 2007).

For suppliers, just-in-sequence became the crucial order winner. It is difficult to imitate and therefore suppliers that learn how to deliver in sequences gain a sustainable competitive advantage. Even though a car manufacturer gains the main advantage from just-in-sequence deliveries, costs of implementation and maintenance are redistributed to the whole supply chain. (Thun, Marble& Camargos, 2007). Suppliers could also use this method upstream, but as the complexity of the materials used decreases relevance and advantages of just-in-sequence deliveries decrease as well. Therefore, the entire supply chain must work together to redistribute profit from just-in-sequence deliveries among its entities. In 2000s a managerial approach that took this fact into account has started to reveal. It was a managerial approach where local optimizations can be sacrificed to enhance system-wide performance (Hart, 2005).

Even though just-in-sequence offers further possibilities for optimization, it is not reasonable for entire spectrum of parts. Therefore selection of right parts is crucial for successful implementation of just-in-sequence. First of all only parts with variants are reasonable for sequenced deliveries. After products with many variants were identified the one which are fastest moving and have the most stable demand should be selected. Parts with unstable demand would not be feasible for sequencing as it would be costly or impossible to do further adjustments to already created sequence of products (Thun, Marble& Camargos, 2007). However, unstable demand can be eliminated by proximity of suppliers supplying just-in-sequence.

Therefore, when selecting just-in-sequence suppliers their proximity is very important. Final sequence is sometimes known only one or two hours before the parts must be delivered to the final assembly line. Therefore suppliers must be able to deliver within hours. Therefore supply parks are usually used to locate these suppliers. There are cases where suppliers supply in sequence even from other countries. However, in this case the sequence must be very stable and it eliminates agility that can be gained from just-in-sequence deliveries. Also in case of a built-to-order model where lead time must be short it would be impossible. Therefore, one can expect to see long distance just-in-sequence deliveries only for forecast based production plants. Other factors influencing the supplier selection are defect ratio and conjoin product development. Just-in-sequence deliveries are very sensitive for defects as delivered defected parts can hardly be substituted. Also, if a supplier works with just-in-sequence deliveries he can understand challenges that come with product variety better and therefore his presence in designing the parts is essential (Thun, Marble& Camargos, 2007).

There are different ways of how a supplier can operate just-in-sequence deliveries. First is that the supplier can produce in batches with subsequent sequencing. In this case the impact of the implementation to the manufacturing processes of the supplier is small. However, it creates higher inventory as all products variants must be stored in batches before put into sequence. The advantage is that sequencing is separated from the production process itself. That way supplier can choose to outsource sequencing to a logistics provider. Second approach is that supplier is producing in required sequence. Implementation has a serious impact on the production processes. However, it further decreases inventory as the manufacturer is producing only what is demanded. The defect ration within the production processes must be very low or zero as interruption of production has an immediate impact on the manufacturer. Also the sequence must be known well ahead so that there is time to produce the required parts. In that case the location of supplier in the supplier park with high proximity is essential (Thun, Marble& Camargos, 2007).

The picture below illustrates three variants of just-in-sequence deliveries.

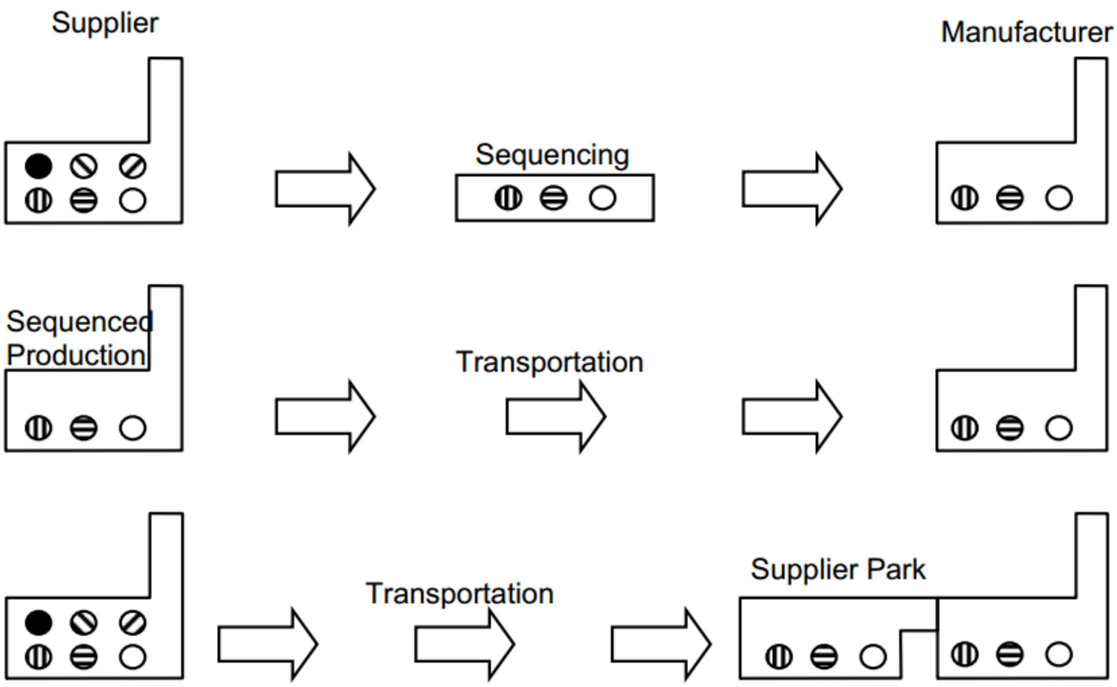


Figure 2-3 Variants of just-in-seqence deliveries (Thun, Marble & Camargos. 2007)

The first case sequencing is done outside the supplier´s and manufacturer´s production plant and it is usually outsourced to a third party logistics company. Example of such third party logistics provider is SEPA Bohemia which operates a warehouse from which they supply just-in-sequence to ŠKODA Auto in Czech Republic. ŠKODA Auto´s suppliers are delivering to this warehouse according to long term orders of ŠKODA. SEPA Bohemia then sequence the parts according to the short term sequence orders and deliver them directly to ŠKODA´s assembly line (Sapebohemia.cz, 2014). The second case illustrates sequenced production and in the third case products are produced and delivered to the manufacturer in batches and then sequenced in the supplier park. Last example will be described closer in the case study of this thesis.

As already mentioned the relationship between the manufacturer and suppliers is crucial for just-in-sequence deliveries. To support fast and clear communication between different entities, electronic data interchange (EDI) is essential. This platform enables sharing of incompatible files between ERP software of manufacturer and suppliers. According to SEPA Bohemia the main advantage of using EDI for just-in-sequence is time saving and human error elimination (Sapebohemia.cz, 2014).

2.4. Validity of the topic

Despite the fact, that just-in-sequence deliveries have been used in the European automotive industry from mid 2000s (Larsson, 2002), it is still a very relevant topic for the automotive industry. According to Parker and Bill Swanton (2003) at the beginning of 2000s only between 30% and 50% of parts were supplied just-in-sequence and it was forecasted to an increase to 70% by 2010. According to the data from the case study, in the year 2014 84% of all parts delivered to two car manufacturers in Central Europe were delivered just-in-sequence. By using the trendline marked by orange colour in the figure below, this prediction can be validated. There are limitation to just-in-sequence deliveries. As already mentioned not for every part just-in-sequence deliveries would make sense. However, according to the supply chain managers and the trend of increasing customization in automotive industry, it can be expacted that this number will even increase in the next years. In the figure is this future prediction marked by the yellow colour.

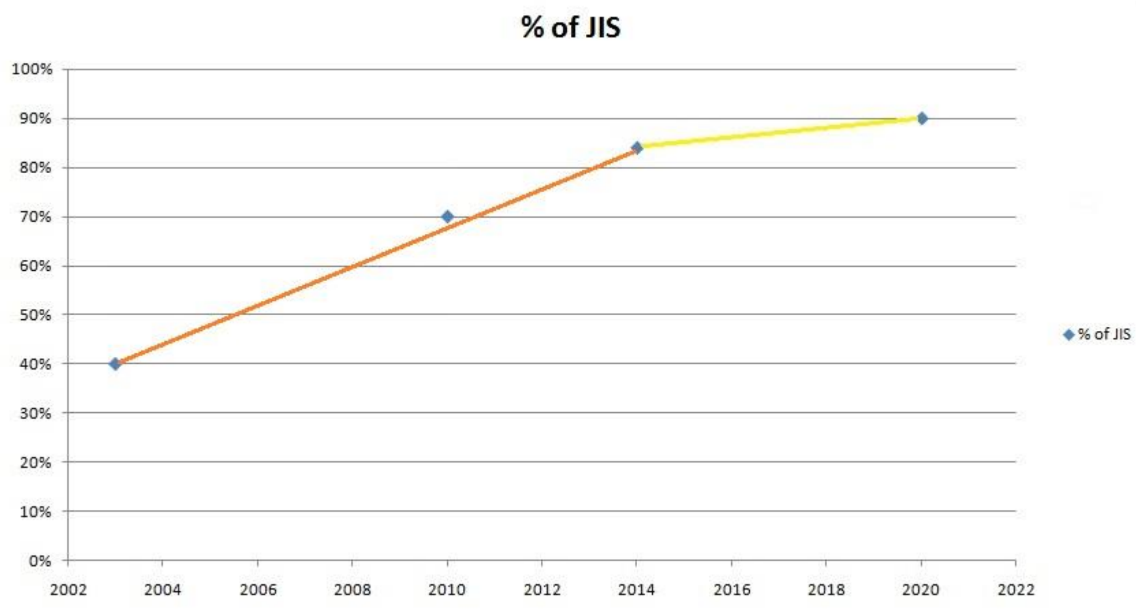


Figure 2-4 % of parts delivered in sequence in automotive inudstry

Another example of car manufacturer in central Europe is ŠKODA. This manufacturer implemented just-in-sequence into its production plant in 2010s (Aimagazine.cz, 2013). By this recent implementation of just-in-sequence the relevance of this method to the current automotive industry can be proven.

Compared to just-in-time deliveries there were only limited empirical studies published during the last decade regarding this topic. A lack of empirical studies is even enhanced by numerous forms of just-in-sequence deliveries mentioned earlier. Furthermore, all of the studies were analyzing relationship between OEM and tier 1 suppliers and excluded impact of just-in-sequence to other entities further upstream the supply chain. On the other hand, the case study in this thesis is analyzing the wider supply chain of OEM, tier 1 and tier 2 suppliers. It is enhancing already published articles by the specific example of tier 1 supplier that is supplying just-in-sequence to the automotive manufacturers in Central and Eastern Europe.

2.5. Conclusion

In the late 1980s and the beginning of 1990s the European automotive industry started to transform into a global oriented industry. High competition forced supply chain managers to look for optimization. Japan and Toyota has been a great example of a successful implementation of lean practices into automotive industry. Lean production and just-in-time deliveries started to form new supply chains in Europe. In contrast with for example the US market, the European market took advantage of the built-to-order model. It has created a good base for customization as the main driver of its competitive advantage in the automotive industry.

At the beginning of 2000s just-in-sequence started to make its way to the practical use to cope with high customization and cost pressure. It has brought many advantages and enabled car manufactures to supply customized cars to its customers within reasonable costs and time.

Even though just-in-sequence has been now known for several years in automotive industry it is still a very relevant topic as there is lack of empirical studies. Another reason is the growing use of this method in the industry. In 2003 in Europe only about 40% of all car parts were delivered just-in-sequence. In the year 2014 84% of the parts delivered to the two main central Europe car manufacturers were delivered just-in-sequence. This trend is to continue and many suppliers will have to deal with this challenge. SEPA Bohemia represents a successful logistic company in Czech Republic which built its business on just-in-sequence deliveries to its main customer ŠKODA Auto in 2010s. Therefore, it can be still seen as opportunity for many logistic providers in Europe.

3. Methodology

3.1. Introduction

The core of this thesis is a case study. Firstly it was believed that case studies could be used only for exploratory research. However, by time it was proven that several famous descriptive and explanatory case studies has had been found among major disciplines including business and engineering (Yin, 2003).

The case study research method tries to understand a real-life phenomenon in depth (Yin, 2003). By employing a case study this thesis tried to understand and explain the impact of just in sequence deliveries on the whole measured supply chain. It tried to give an overall multi facility point of view that has been missing. A case study and dominant qualitative analyses was selected as the best option to illustrate and explain complex processes with many variables in detail.

In order to find the answers and to describe the processes, the adopted methodology was based on the case study strategy described by Yin (2003).

3.2. The research philosophy

A research philosophy is an important base stone of each research as it explains the worldview with which the research is identified (Quinlan, 2011). It influences research design as it indicates what kind of evidence is needed in order to prove the outcomes of a research. Clarity in what data and information are reliable for the research and which cannot be considered as valid, prevents researcher from going up too many blind alleys (Easterby-Smith, Thorpe & Lowe, 1991).

There are many research philosophy approaches. It is not likely that only one philosophy is present in a research. However, by identifying the most dominant philosophy, by which an outcome was conducted, generated knowledge can be understood better by the readers of this thesis.

Most of debates about the research philosophy concerns ontology and epistemology (Easterby-Smith, Thorpe & Lowe, 1991). Ontological questions are questions about the nature of reality (Quinlan, 2011). According to

Easterby-Smith and Thorpe & Lowe (1991) there are two main ontological approaches: subjectivism and objectivism.

3.3. Ontology

Subjectivism asserts that social phenomena are created from perceptions and actions of social actors (Saunders, Lewis & Thornhill, 2003). For example each manager in a measured supply chain can have a different perception of the same problem or challenge. Subjective perspectives are important for this research as most of the information was obtained through interviews.

On the other hand objectivism represents a position where social actors exist in a reality independent from actions of other social actors(Saunders, Lewis & Thornhill, 2003).This approach was dominant especially in the final part of this research as a Value Stream Map was supposed to objectively map current state of multiple production plant´ s supply chains.

Each production plant manager can see challenges that his production plant is facing in respect to its customers and suppliers. However, an objective overall picture can bring further possibilities for improvements of the entire supply chain. The most important is what is good for the entire supply chain rather than for each entity individually. Therefore, objectivism will be required for the implementation of improvements as they may penalize some entities in the supply chain while favour the others.

Interviews were strongly enhanced by quantitative analyses which was also highly objective. Therefore even thou subjective perspective was taken during individual interviews outcome of this thesis should be taken from an objective overall supply chain perspective rather than from a one facility point of view.

3.4. Epistemology

Epistemology is about the methodology and methods used in the research project. It relates to the understanding of knowledge and how it was created. Therefore it also determines the validity of new knowledge generated by research projects (Quinlan, 2011).

There are some researchers that are resource oriented. That means that they seek for facts in order to carry out any analyses. On the other hand some researchers are keener to use data from feelings and attitudes of social actors. Each approach has its advantages and disadvantages (Saunders, Lewis & Thornhill, 2003).

While drawing the Value Stream Map it was assumed that not everything that the researcher is able to observe by his senses can be understood correctly. Critical realism recognizes these phenomena and recommends using observed reality as sensations which must be further analysed. Therefore, further analyses of the observed value stream are done by interviews and quantitative analyses. Interpretivism is the dominant philosophical approach of the interviews in this research. While conducting interviews the researcher is interested in the manager´s opinion and his role as a social actor (Saunders, Lewis & Thornhill, 2003).

The philosophy of positivism prefers collecting data about an observable reality. According to positivism, only attributes that can be observed can lead to credible data (Saunders, Lewis & Thornhill, 2003). The key idea of positivism is that world´s properties should be measured through objective methods (Easterby-Smith, Thorpe & Lowe, 1991).

So similarly to previous ontology of objectivism, positivism is one of the approaches used in this thesis. On site data collection and ERP software data analysis are all part of the positivistic approach of the researcher.

3.5. Design of research

This research has a single-case design which means that it analyses only one case study. Single-case study design can have a significant contribution to already existing knowledge as it is representing unique examples (Yin, 2003). Just in sequence deliveries has been known in automotive industry for several years. However, a conducted case study of this research is an example of just in sequence supply chain rather than one facility. Therefore its outcomes provided further information in this field.

Three entities are involved in the case study. Each is analysed separately and then put into overall picture of the whole supply chain. Even known there are more units of analyses, the entities' interaction was crucial for the thesis. Therefore, this thesis dealt with an embedded single-case study which is focusing on subunits of one entity (Yin, 2003). In this case, individual manufacturing plants in one supply chain.

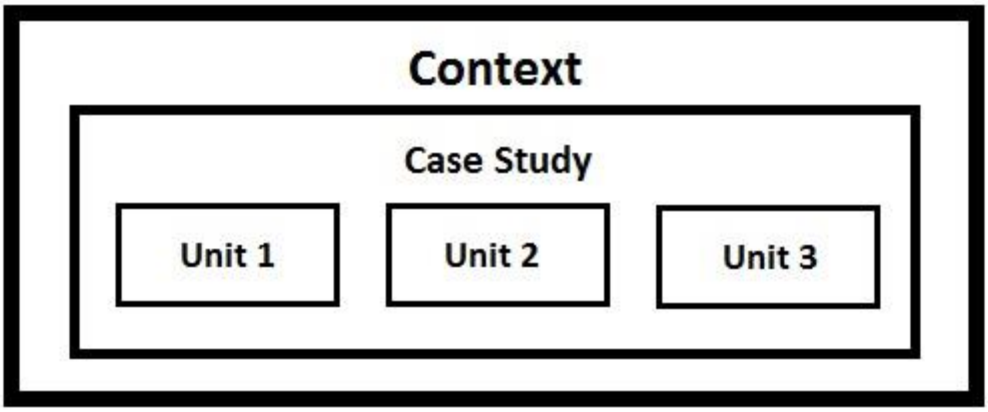


Figure 3-1 Embedded single-case study design

When units are transformed into specific entities, scope of this research can be seen as illustrated in the figure bellow.

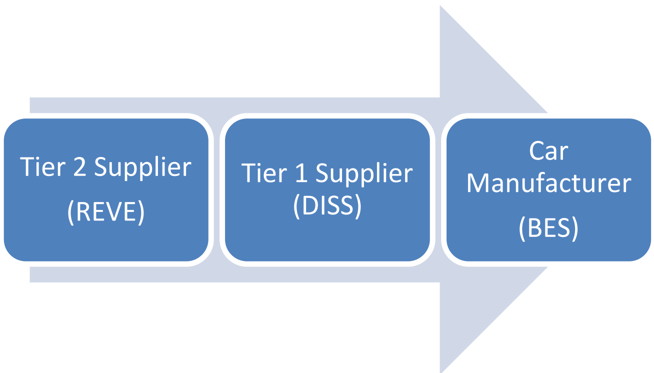


Figure 3-2 Scope of this research

These three companies represent the empirical research in this thesis. Both quantitative and qualitative information were gained from them to enhance validity of this research. Below the schematic figure of this research design can be seen.

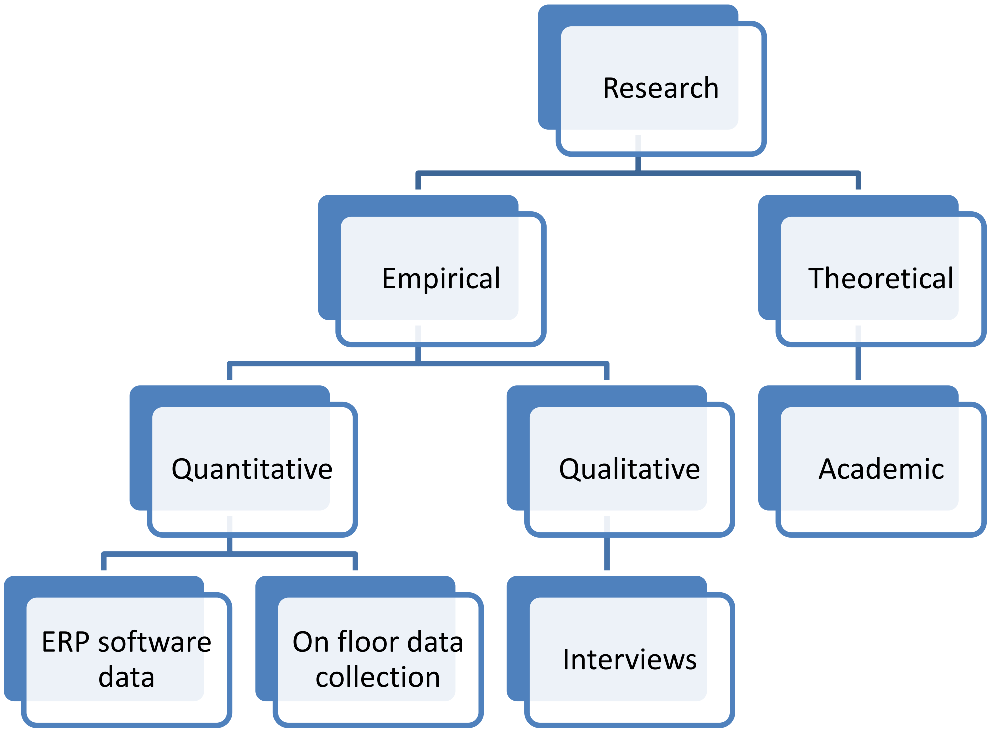


Figure 3-3 Schematic figure of the reseatch design

The figure above indicates how the data was collected. This thesis was mapping the flow of a product through 3 levels – raw metal pipes, car part, finished car. The table below illustrates the availability of information from each measured entity.

	Production plant tour	Supply chain manager interview	E-mail communication	On floor data collection	ERP software
Car manufacturer (BES)	Yes – 3 hours	Yes - partly	No	No	No
Tier 1 supplier (DISS)	Yes – more days	Yes - strong	Yes - strong	Yes	Yes
Tier 2 supplier (REVE)	Yes – 3 hours	Yes	Yes	No	No

Figure 3-4 Information availability

The main part of the information about the car manufacturer came from the production plant tour and the supply chain manager interview. However, focus was given only to the part of the production plant where DISS is engaged. It means from the point where their products are installed on the cars upstream the supply chain. An interview was conducted with a manager responsible for this part with no further information about downstream processes or information flow.

A plant tour was also done at the DISS´s site. Access to the production plant was given for several days with or without the manager. Interviews were taken before, during or after the tours to answer questions and propose further actions. On site data collection was allowed which was enhanced by data from the company´s ERP software.

REBE supplier was difficult to approach due to its location. However, 3 hours production plant tour with supply chain managers' interviews took place. Afterwards e-mail communication could be held to clarify information or obtain new one. However no access to ERP software neither on site data collection was allowed due to high sensitivity of the data.

From above mentioned it is clear that the best information access was from DISS. Therefore, this company will be analysed with the biggest focus. However, by extending the view from the tier 1 automotive supplier to the car manufacturer and tier 2 suppliers, this thesis promises to explore impacts of just in sequence deliveries on the wider supply chain.

The researcher was observing the current state of the supply chain with no impact on its processes during the research. From this perspective the thesis is only describing events as they normally occurred during the time horizon of the thesis. However, the outcome of this thesis were analysed and logical recommendations were given (Sekaran & Bougie, 2010).

The Value Stream Map represents one-shot picture of current value stream. However, all the numerical data in the Value Stream Map were modified using basic statistical methods to improve their validity. For this purpose June 2014 was selected as a demonstrative month. The Value Stream Map therefore represents the supply chain as it was in June 2014.

3.6. Data collection methods

Data can be gained from primary or secondary sources. Secondary data refers to information gathered by someone else then the researcher. The general advantage of secondary data is that they are much less time and money consuming then primary data (Ghauri, Grønhaug & Kristianslund, 1995).

However, for the purpose of this thesis secondary data also had another advantage. Even though that the literature recommends to collect lean data from production plants by the observer himself, DISS´s production processes are so complex, that trying to measure cycle times, machine availability and inventory levels on the floor in scope and time frame of this thesis could be misleading. Therefore, internal data for the case study were obtained through the company´s ERP software. Other secondary data were obtained from books and internet.

Primary data are the one obtained by the researcher himself and especially for the purpose of the research. Examples of such sources of data can be individuals, focus groups, panels and unobtrusive methods (Sekaran & Bougie, 2010).

In this dissertation primary data were collected by production plant tours and individual interviews. From time to time tours and interviews were joined by other people to discuss an issue. However, generally no more than 3 people were present at one interview.

Interviews might generate both qualitative and quantitative research. However quantitative data may be obtained only by highly structured interviews (Quinlan, 2011). For the purpose of this thesis, interviews were used to generate qualitative research. The data from ERP software was used for quantitative research to enhance the interviews.

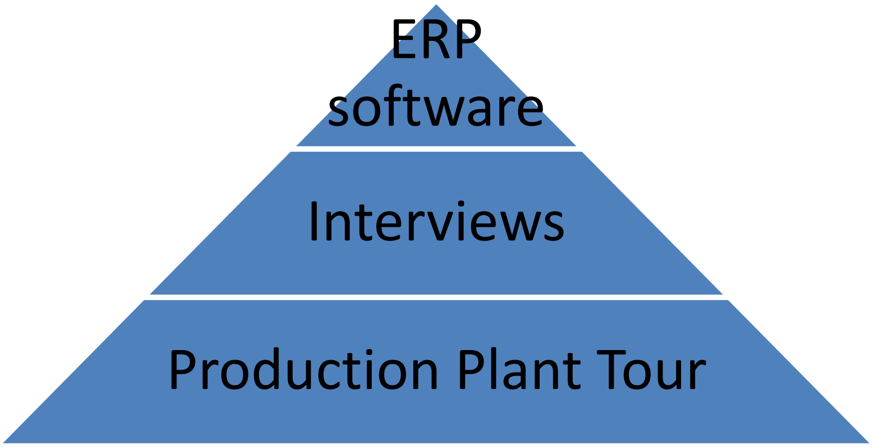


Figure 3-5 Sources of information

3.7. Qualitative analyses

Qualitative analyses were dominant in this thesis. It is based on non-numerical data. Therefore, it can come in almost any form such as feelings, beliefs, perspectives or opinions. It can be in forms of stories, photographs but also maps, such as the Value Stream Map drawn during production plant tours (Quinlan, 2011).

An interview is one method of collecting data. Interviews might be face to face, by telephone, or online. There are structured and unstructured interviews and each has different advantages and disadvantages (Sekaran & Bougie, 2010).

There is no planned sequence of questions to be asked at unstructured interviews. The main advantage is that by unstructured interviews, the interviewer can bring unknown issues to the surface (Sekaran & Bougie, 2010). By taking a manufacturing plant tour, the flow of material could be seen and recorded. However, to understand the flow it was very important to understand the different challenges of the supply chain. Also, each production plant is very different in its nature as they come from different industries. That is why unstructured interviews were selected for this research.

All the interviews were held before, during and after the production plant tour and all the data collected at the interviews represented June 2014 as a sample month. Tours were taken with upstream direction. It means that the first tour of the measured supply chain was taken closest to the customer and followed upstream processes. The point of the measured supply chain, which is the closest to the customer, is where the DISS´s product is assembled on a car at the BES´s assembly line.

By following the processes upstream, pull factor perspective could be taken from the very beginning which is essential for automotive industry. Each tour was specific as the nature of the manufacturing plants was totally different due to the fact, that each comes from a different industry. Therefore, different issues were discussed during each tour.

The first tour was taken at BESS, starting from the point where cars are leaving the production line. However, the research was allowed to take only a fast glance to the first processes of the car manufacturer. Deeper focus was given only to the part of the plant connected with the DISS´s deliveries. The issues discussed were:

- BES´s production flow
    - Production plant layout
    - Production workshops
- Just in sequence deliveries
    - Consignment warehouse
    - Kanban system
    - Just in Time vs. Just in Sequence
    - Cycle time

    - Information flow
- Safety stock
    - Consignment warehouse safety stock
    - Winter time warehouse safety stock

The second tour was taken at the DISS´s manufacturing plant. Starting from the distribution where trucks are loaded to deliver six times a day. Then the walk led through each production process ending in the consignment warehouse where the raw materials are stored. The issues discussed were:

- DISS´s production flow
    - Production plant layout
    - Number of workers
    - Production steps
    - Batch sizes
    - Warehouse system
- Inventory level control
    - Kanban system
    - WIP inventory control
    - Finished Goods inventory control
- ERP software
    - Data management
    - Forecasting/Planning/Ordering
- Deliveries to the car manufacturer

The last tour took place at the floor of the most upstream production plant of this thesis – REVE the tier 2 supplier. The time pressure did not allow the researcher to have more than a quick walk through two main lines of the production: CBL and ACC line. Afterwards interviews with supply chain and logistics managers took place regarding:

- REVE´s production flow
    - Production plant layout
    - Number of workers
    - Two production lines

    - Batch sizes
    - Warehouse system
    - Inventory levels
- Deliveries
    - Weekly deliveries to the tier 1 supplier
    - Weekly deliveries from its suppliers
- Extended services
    - Cutting, Pressing and Nut Instalment

Mostly qualitative analyses of the processes were used for REVE and the BES where little data could be gained. Data about the average production capacity, cylce time and inventory levels were only gained verbally during the interviews after the tours.

3.8. Quantitative analyses

However, for DISS where the production is more complex compared to REVE, further quantitative analyses must have been done to support the interviews. Simple descriptive statistics to describe the data was used (Quinlan, 2011). June 2014 was selected as a sample month for secondary data as well as for the quantitative analysis. At the time June 2014 was the most actual month with all the data available.

These reports were gained from the ERP software:

- Hours/Daily/Monthly Plans
- Operations per machine
- Defect ratio
- Standard production times
- Bill of materials
- Inventory levels

As these reports also included excessive data which was not important for this thesis, data must have been reduced. Data were narrowed only to a specific time period and a specific part number. Also the data needed to be transformed.

Some irrational values occurred due to human errors such as negative inventory. By excluding these irrational values the data became more credible (Sekaran & Bougie, 2010).

First of all a demand needed to be measured to select a fast moving product to focus on. The data of daily deliveries was used to measure the demand of each product. As each product consists of several parts, after selecting the product with the highest demand, the bill of materials was required to break it down into simple parts. By comparing the bills of materials and the demands it became clear which part was used the most. Some parts were used for more products so demands must have been added together to find the fastest moving part. In case there were more parts with similar demands the one with the longest production time was selected. A part with a longer production time is more likely to create a bottleneck in the production compared to the other parts. Therefore, the fastest moving part with the longest process time was selected.

After selecting a specific part of a product it was clear which data to look at. As already mentioned, due to the complexity of the production, averages from ERP software were considered more precise, than actual measurements collected by the researcher on the floor. Process times from ERP software for each process step were gathered to indicate the cycle times. At this point it is important to specify what cycle time means, as it can have many definitions (The Lean Thinker, 2010). In the case study conducted by this report cycle time represent the time, that it takes for one machine to process one part. These times can be found in the process boxes of the Value Stream Map.

A big challenge came with the machine capacity. Due to large amount of different products that flow through different process steps with different process times finding bottleneck was very difficult. In other words, each machine is producing a different amount of parts. Each part has a specific process time due to different parameters. Furthermore, capacity of each machine can be optimized by increasing number of operators. Therefore, combination of calculating process cycle time and empirical analyses was taken.

Lead time in days, for each inventory is calculated as inventory quantity divided by the daily customer requirement (Rother & Shook, 2003). Averages were calculated from 3 measurements each week in the June 2014, which were taken each Monday, Wednesday and Friday.

$$\text{Inventory} = \frac{\text{inventory quantity}}{\emptyset \text{ daily customer requirement}}$$

3.9. Tools used

A Value Stream Map was used to illustrate product flow through the measured supply chain. There are several reasons for this.

First of all value stream mapping is a lean tool which is able to visualise more than just a single process. It has the ability to visualise the flow through several processes and even through several manufacturing plants. This ability is essential to the objectives of this research. Induction of the lean principles with this tool is also very important for automotive supply chains where lean is an important factor (Holweg, 2007). According to Industryweek.com (2014), a Value Stream Map represents one of the most fundamental tools associated with lean production to eliminate wastes. Despite this fact, DISS has never drawn a Value Stream map of their supply chain. This gap was seen as an opportunity for the company to apply further improvements to enhance their just-in-sequence deliveries.

Most of the other lean tools such as “Six Big Looses”, “Muda” or “Kaizen” enable user to see the wastes in their supply chain. On the other hand Value Stream Mapping allows researcher to see the sources of the waste. It forms a design of manufacturing plant´s material and information flow from door-to-door or even from one plant to another (Rother & Shook, 2003).

Increasing single machine and labour utilization is one thing but seeing waste in an entire supply chain is another. When the focal plane is changed from own assets to the product itself and what is happing during its long journey, one may realize that a performance of the entire value stream is abysmally sub-optimal. No other tool does look at the entire supply chain as the Value Stream Map

(Jones & Womack, 2002). The Value Stream Map helps managers to implement system, rather than one process improvement. It has been identify as a tool to improve both national and international competitiveness (Emiliani & Stec, 2004).

The point of creating a Value Stream Map is not the map itself, but understanding the flow of information and material (Rother & Shook, 2003). However, after drawing a value stream on paper, it is essential to redraw it using a computer. That way it is readable for everybody else who is reading this research.

There are several engineering programs that offer Value Stream Mapping. Some of them are free to use or at least have free trial periods such as:

- SmartDraw
- Edraw Visualization Solutions
- Lucid Chart
- VISIO (Microsoft office)

However after a deeper analysis Excel was selected. All the necessary symbols can be drawn using shapes in excel and further lean calculation can be done easily using functions all at one place in a spreadsheet. For the purpose of this thesis there were no advantages from using some of the above mentioned software.

3.10. Drawing the Value Stream Map

When approaching the production plant, simple pencil and paper were the best way to sketch the value stream. Drawing by hand during the production plant tour had several advantages. It could be drawn without a delay, while the researcher was on the floor. While drawing participants could be already thinking about other information necessary. It also helped the participants to keep their focus on the value stream rather than thinking how to use a computer (Rother & Shook, 2003).

A Value Stream Map should be illustrated in common language so it is easy to understand (Jones & Womack, 2002). This language is illustrated by icons listed in appendix A of this research.

3.10.1. Blue Area

Blue part of the value stream map represent supplier park of the car manufacturer. Therefore, it includes BES´s assembly line marked as “BES” and sequencing warehouse for the tier 1 supplier marked as “FGS”.

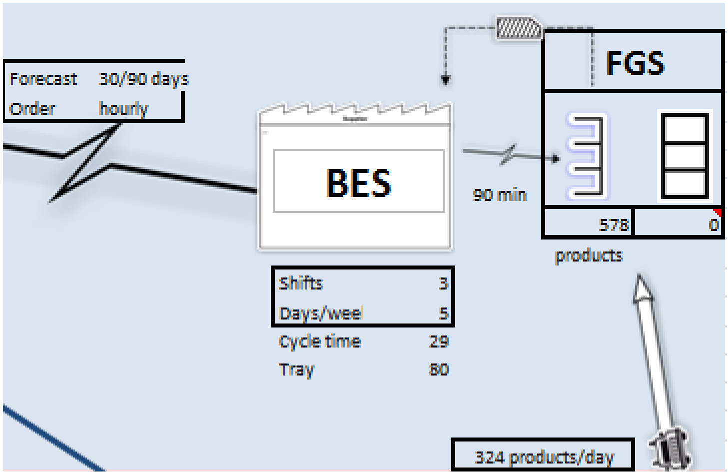


Figure 3-6 Blue Area of the Value Stream Map

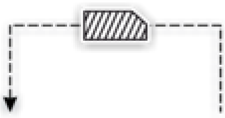


Figure 3-7 Kanban tray supplying in batches

Figure 11 illustrates Kanban trays that are moving parts from the FGS warehouse to the assembly line in batches. Batch size together with shift pattern and cycle time of the assembly line can be seen in the cells under the entity/assembly line icon.

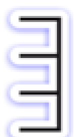


Figure 3-8 Supermarket

Figure 12 illustrates a supermarket from which the break and fuel bundles are pulled directly to the assembly line. This supermarket is located at the FGS warehouse where the kanban trays are filled in with the parts at the required sequence. Numbers in the cell under the icon represents inventory. For example there are on average 578 pieces of products at the FGS warehouse.

Figure 3-9 Truck deliveries

Figure 13 shows deliveries and the form of transport mode. In the measured supply chain only road transport is used between the three production plants. Values next to the arrow are frequency and the amount of products delivered per period of time.

3.10.2. Red Area

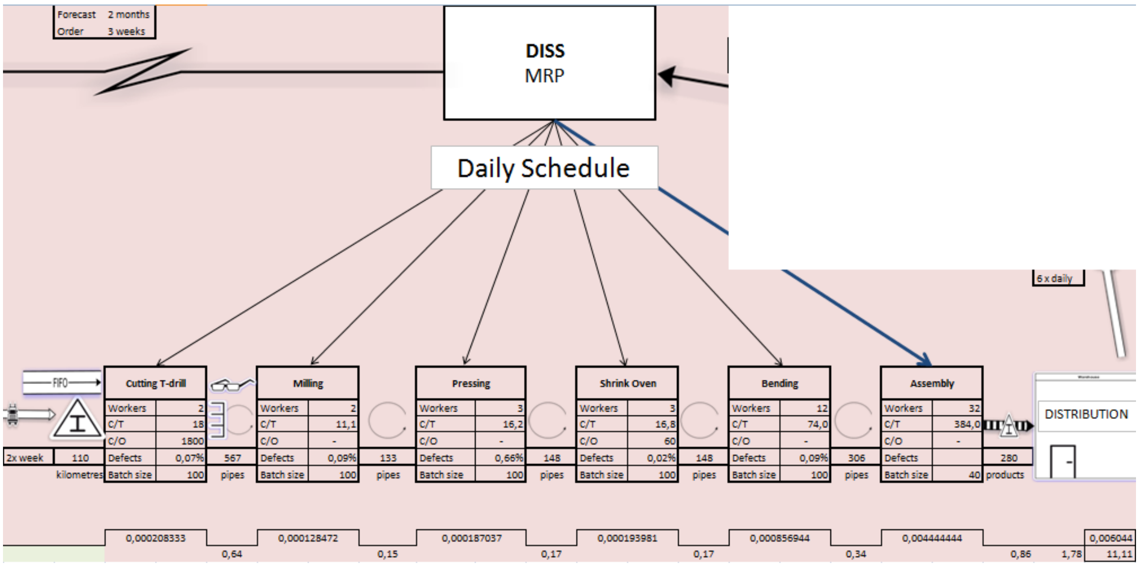


Figure 3-10 Red Area of the Value Stream Map

Process boxes are used to indicate individual processes. To use one box for every single process in the production would make the map cluttered. That is why one box represents one material flow. The process box ends wherever processes are disconnected and inventory is created. Between each of the process box material flow is disconnected, material is moved in batches and inventory is created.

There are 6 processes boxes plus the distribution.

1. Cutting T-Drill
2. Milling
3. Pressing
4. Shrink oven
5. Power Bending
6. Assembly

Each process box has its data box with:

1. Number of workers
2. Cycle Time (C/T)
3. Change over time (C/O)
4. Defects
5. Batch size

Inventory is accumulating between every process box. This is represented by the number of products, cut pipes, or kilometres of the pipe between each process box. For example on average, there are 280 products at the distribution.

All the inventory levels measured in number of products or parts are transferred into days by using an average demand. Inventory in days is displayed on the timeline below the Value Stream Map. It is tempting to think that transportation times should also be included in this timeline. However, all entities in the measured value stream are using consignment warehouses. That means that they have two finished goods warehouses, one at their and another at their customer´s site. ERP software still counts with the finished goods inventory as being stored even though this inventory is physically changing the location and is being transported. Therefore in this case, the transportation times are included in the inventory time.

3.10.3. Green Area

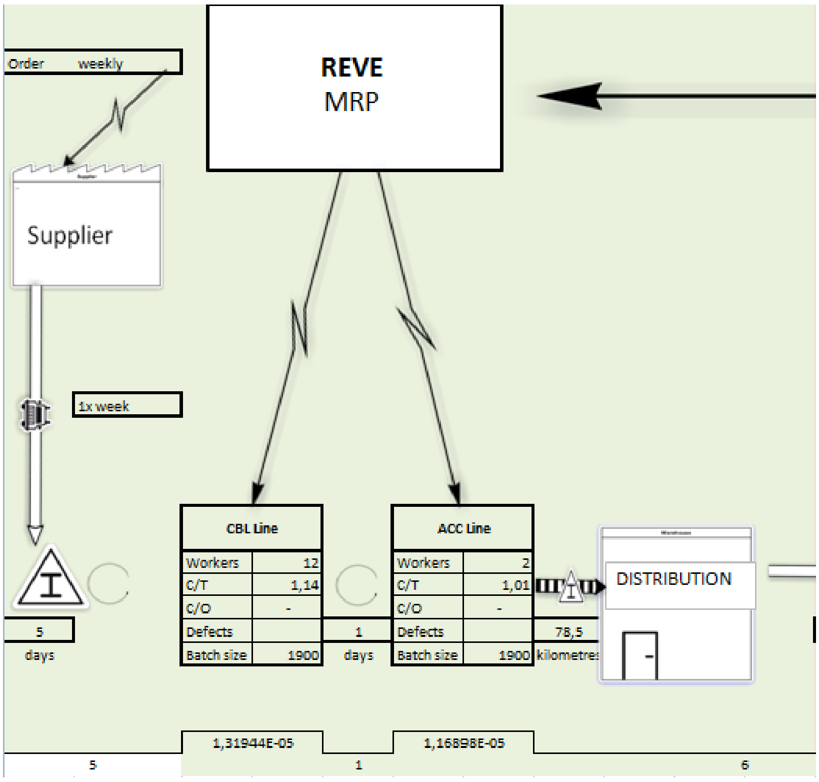


Figure 3-11 Green Area

The green part of the Value Stream Map represents tier 2 supplier. The map consists only from two process boxes even though the production process is more complicated than what could be an impression from their Value Stream Map. The reason for this is that the material flow is interrupted only once between the ACC and CBL line. Otherwise REVE´s map does not consist anything that has not been already mentioned. As there are more raw materials that differ in its nature, they are expressed by days between the process boxes.

3.10.4. Timeline

Timeline is located at the bottom part of the value stream map. It is used to illustrate value adding and non-value adding activities. Therefore, inventory must be transferred from the number of materials and products into days by the already mentioned formula: $\text{Inventory} = \frac{\text{inventory quantity}}{\emptyset\ \text{daily customer requirement}}$

4. Case Study

4.1. Introduction

This thesis is examining impact of just-in-sequence deliveries on the supply chain of car manufacturer - BES, tier 1 supplier - DISS and tier 2 supplier - REVE. There are many interactions between entities in the measured supply chain. Sometimes it is difficult to clearly state whether a discussed process belongs to one entity or the other as the supply chain is using consignment warehouses and external sequencing warehouses which are operated by one entity but owned by the other. Therefore, the drawn Value Stream Map from the appendix B and C is divided into three parts highlighted by colours. This case study will refer to the blue area – BES´s supplier park with external finished goods sequencing warehouse (FGS warehouse), the red area - DISS´s facility with consignment warehouse of REVE and the green area – REVE´s facility with consignment warehouse of its supplier. It is highly recommended to have the Value Stream Map from the appendix on hand while reading the case study.

4.1.1. Car manufacturer - BES

In fact BES operates two modern plants built in 2006 which are located 85 kilometres apart in Central/Eastern Europe. They are producing 3 car types each, which are delivered worldwide. Each manufacturing plant is working on 3 shifts with 5 working days and has a cycle time of 58 seconds. 58 seconds cycle time enables maximum production of 1486 cars a day. Together they have average production of around 670 000 cars per year which is steadily increasing. Both of the manufacturing plants are similarly big and modern. Therefore, they face very similar challenges and their relationship with tier 1 suppliers is identical. They are both located approximately 40km from the DISS supplier which supplies break and fuel bundles to them. Information flow between them is also similar as both communicate with DISS supplier through the same ERP software and require the same delivery conditions. Therefore, for the purpose of this paper the two manufacturing plants are merged into one which is called BES. It will significantly improve clarity of the thesis. However, as we merge the two manufacturing plants into one, production is increased to

2972 cars a day with cycle time of 29 seconds as shown in the Value Stream Map. The figure below illustrates the real performance of each individual assembly line versus adjusted performance of one manufacturer – BES; for purpose of calculations in this research.

	BES (two assembly lines)	Each individual assembly line
Cycle time	29 seconds	58 seconds
Maximum production	1486 cars a day	2972 cars a day
DISS´s batch size	80 products	40 products

Figure 4-1 Real vs. Adjusted performance of the assambly lines

BES has 63 suppliers. Approximately 80% of these suppliers are located in Central and Eastern Europe and the rest are in Western Europe and Asia. From this ratio it can be assumed that proximity is important for the manufacturer. BES developed Supplier Park around its assembly line. Some of the suppliers have their entire production plants located in this park. However due to area constraints not all of the suppliers could be placed inside.

BES is working on three 8 hours shifts with 10 and 20 minutes breaks. Their production is very lean with just-in-time and just-in-sequence supplies. Just-in-sequence deliveries are required for maintaining sequenced production of cars. In sequenced production cars are put on a TRIM assembly line in sequence according to the demand. Therefore, it is built-to-order production. This way flexibility in manufacturing hundreds of car modifications can be maintained with very little inventory. However not every parts are delivered just-in-sequence. It is only rational for parts with high product variety. Therefore, parts which are the same for all models are delivered just-in-time. Another example of just-in-time supply is parts, which require further assembly on site. However, after additional assembly on site, all the parts must be put into a sequence before reaching assembly line.

4.1.2. Tier 1 supplier – DISS

DISS supplies directly to BES and produces Brake and Fuel and Break Bundles. As mentioned before it is located 40km from BES to ensure just-in-time and just-in-sequence deliveries. Its yearly turnover is approximately

30 000 000 EUR with around 300 employees. It is part of DISS Group which is specializing in automotive industry.

Their only customer is BES; therefore their production is directly derived from the production of this manufacturer. They produce over 200 000 items per month out of which, around 60 000 are the break and fuel bundles. For reasons that will be mentioned in the - Selecting the product type section, the case study focuses on the break and fuel bundles.

In the table below there is a list of break and fuel bundle types for each car type.

BES	
CAR TYPE	# OF BUNDLE TYPES
YN	3
JD	6
SL	10
GD	4
JC	2
EL	10
TOTAL	35

Figure 4-2 # of byndle types per car type

The reason for having more brake and fuel bundle types for one car type is a customization. Different car modifications have different structures of brake and fuel bundles. However, due to the fact, that some car types are sharing the same design of the bundles there are all together 28 different break and fuel bundles.

By the number of products it can be seen that complexity of production is high. Each break and fuel bundle has both metal and plastic pipes which are produced on a metal and a plastic production line. There are 182 machines used just for the metal production line:

- 2 cutting T-drills
- 6 cutters (milling process)
- 9 pressers
- 2 shrink ovens
- 1 automatic bender

- 162 manual benders

Complexity of production derived from the high number of product types and production processes is an important aspect, as it is a major constraint for implementation of further lean processes.

To fulfil the customer´s requirements the location of DISS is very important. It is located 40km from BES. By truck BESS can be reached in 40 minutes. Proximity gives DISS flexibility which is essential for just-in-time and just-in-sequence deliveries. On the other hand, DISS has 12 suppliers from all around the world. They have one local supplier and several from all around Europe such as Italy, Germany and France. Many parts are delivered from Asia as all the products and machines are designed there.

4.1.3. Tier 2 supplier - REVE

The name of the tier 2 supplier measured in this thesis is REVE. REVE is a metal pipe manufacturer located in Germany. It produces metal pipes with 4mm diameter used mainly in automotive industry. Its main customers are located in Poland, Czech, Slovakia, Germany, Belgium and Spain. They supply 4mm metal pipes to DISS for break and fuel bundles production.

REVE´s product portfolio is significantly lower compared to DISS and BES as the 4mm metal pipe is their only product. Additionally, they provide cutting of the metal pipes into required length and nuts instalment. Nuts can be added at the ends of the pipes to prepare them for assembly. This requires further milling and pressing of pipes which can also be done by REVE supplier. However, these additional services are not used by DISS. DISS is cutting, milling and pressing the pipes at their own site. So far REVE is providing these additional services only to its German customers.

REVE is very lean and automated production. Its maximum capacity of 2500 km of 4mm metal pipes per week can be achieved by working on Saturday and Sunday and with 4 shifts per day. Each shift is working 6 hours a day without any break. First shift is starting at 6 in the morning.

4.2. Selecting a product part

The main focus of this thesis is on the tier 1 supplier. DISS supplies 78 products to BES. From these the biggest product family is Brake and Fuel Bundles. Brake and Fuel Bundles merit for 49% of sales while they merit only to 38% of their product portfolio and 30% of produced items.

Usually they are composed of 2 metal pipes, 3 plastic pipes and several protections and clips, which hold them together and prevent them from scratches. All protections and clips are supplied directly to the assembly table, which is the last step of DISS´s production, by a kanban cart. It means that they do not flow through other steps of production. Therefore, a metal or a plastic pipe should be selected to track the value stream through the entire manufacturing plant.

Both the plastic and the metal pipes have their own production line as the production process differ significantly. The plastic line has 4 process steps:

1. Cutting Santroprene
2. Assembly Santroprene
3. Hot Forming
4. QC Insertions

On the other hand the metal line consists of:

1. Cutting T-drill
2. Milling
3. Pressing
4. Shrink Oven
5. Power Banding

After 3 plastic and 2 metal pipes are processed they are assembled together to create a brake and fuel bundle at the assembly table mentioned before. Figure below illustrates break and fuel bundle. Two blue lines represent metal pipes and three red lines plastic pipes.

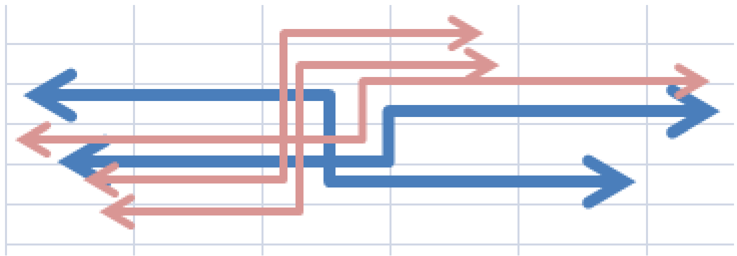


Figure 4-3 Illustration of a break and fuel bundle

Each metal and plastic pipe has different lengths and diameters and can be supplied from different suppliers. Therefore selecting one pipe from one supplier is essential for feasibility of this report.

As we can see in the table below the three fastest moving (according to the demand) brake and fuel bundles are 31300-2Y200, 31300-2Y330 and 31300-A6900. As it will be observed later, 31300-A6900 is composed of parts that are also used in other break and fuel bundles as well. That is why this bundle was selected.

Brake and Fuel Bundle	Average Weekly Demand
31300-2Y200	2000
31300-2Y330	1648
31300-A6900	1620
31300-2Y600	1288
31300-A6100	1200
31300-1P000	1087
31300-2Y330	920
31300-2Y650	888
31300-A6200	870
31300-2Y600	632
31300-A6000	610
31300-2Y650	424
31300-3U080	344
31300-1P900	325
31300-3U180	304
31300-2Y400	296
31300-3U400	224
31300-2Y180	192
31300-A2300	150
31300-2Y080	144
31300-A2400	96
31300-3U450	64
31300-1P100	63
31300-2Y450	56

31300-2Y130	40
31300-3U130	40
31300-3U030	32
31300-2Y030	8

Figure 4-4 Weekly demand of break and fuel bundles

31300-A6900 is composed of 2 metal and 3 plastic pipes as listed below.

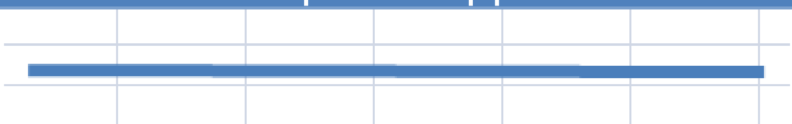
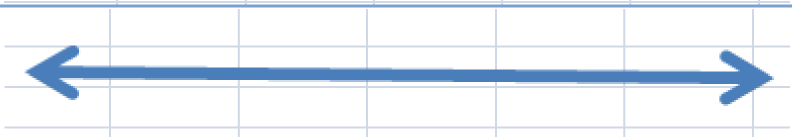
31300-A6900	Part Number
Metal Pipe 3269mm	58735-A6300
Metal Pipe 4212mm	58736-A6300
Plastic Pipe 3030mm	31310-A6900
Plastic Pipe 415mm	31310-A6950
Plastic Pipe 3445mm	31339-A6900

Figure 4-5 Parts of 31300-A6900

However, both the metal pipes 58735-A6300 and 58736-A6300 are also used in brake and fuel bundles: 31300-A6000; 31300-A6100; 31300-A6200; 31300-A2300 which makes them the fastest moving part with average weekly demand of 4450 pipes. That is why the metal line should be selected.

These two metal pipes undergo similar but not identical production processes. Both of them go through similar production steps but due to the differences in size the cutting t-drill and the bending operation differ in production times. Total production time of shorter 58735-A6300 is 115.03 seconds and longer 58736-A6300 is 136.03 seconds. Therefore, improving the production of the longer metal pipe should be the main focus to improve DISS´s manufacturing plant performance.

58736-A6300 part is made of metal pipe with diameter of 4mm which is cut, milled, pressed, sealed in the shrink oven and bent as illustrated below.

Operation	Impact on the pipe
Cutting	
Milling and Pressing	

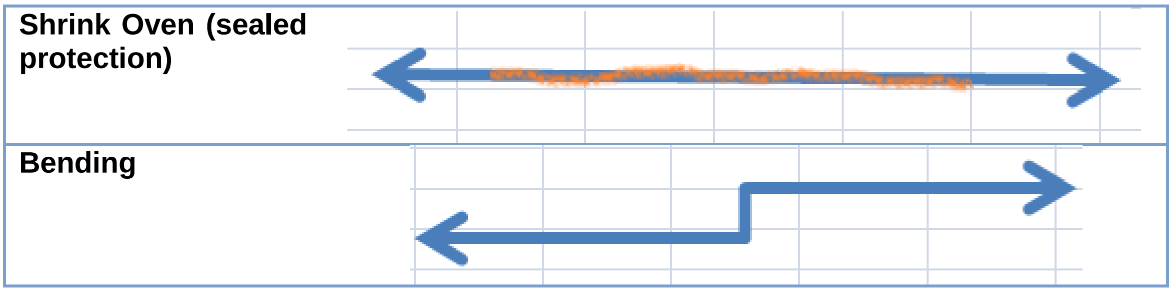


Figure 4-6 Impacts of operations on the part 58736-A6300

Material for this pipe is supplied from a supplier located in South-West of Germany.

Level	Car Manufacturer (OEM)	Part production (Tier 1)	Raw Materials (Tier 2)
Name	BES	DISS	REVE
Location	CEE	CEE	Germany

Figure 4-7 Measured supply chain

The purpose of this thesis is to map the value stream in an entire supply chain rather than just one facility. Narrowing down our concern only to the part 58736-A6300 will enable us to achieve this in a manageable way. The mapping of the companies BES, DISS and REVE will not give us the entire supply chain point of view but multiple facilities point of view, which will be sufficient for the scope and time frame of this thesis.

4.3. Pulling the sequence

4.3.1. Blue Area – Supplier Park

The manufacturing plant consists of 3 main parts: Welding Shop, Coating Shop and Final Assembly Line. Around the manufacturing plant, BES developed a supplier park which is represented by the blue area in the Value Stream Map. Some suppliers have their entire productions located in the supplier park. Some other suppliers that are located outside the supplier park and are delivering just-in-sequence are using FGS warehouse that is located nearby the assembly line.

4.3.1.1. Just in Sequence

Coating Shop is a very important point of production for suppliers such as DISS. It is important because this is the last point where the sequence can be modified. After Coating Shop cars are put on the TRIM assembly line and sequence is final. If suppliers fail to deliver required parts in the right sequence the production line must be stopped. This causes heavy losses to BES and penalties for tier 1 suppliers. Therefore quality of deliveries, timing and proximity of suppliers are crucial.

The location of a supplier´s workshop on the production line determines how long the supplier knows a sequence before a car reaches its workshop. This is also a time that suppliers have to deal with potential problems after a car is put onto the sequenced production line. For DISS it is approximately 90 minutes. It means that if they fail to fulfil production line requirements within 90 minutes from the time when they are informed about final sequence the line must be stopped.

90 minutes is relatively short time. BES has been able to achieve such a short reaction from its suppliers by providing them the FGS warehouse. FGS warehouse is located right next to the assembly line. For comparison, company SEPA Bohemia that is supplying just in sequencing to ŠKODA from outside the assembly line, must know the sequence 120 minutes before the parts are needed at the assembly line (Aimagazine.cz, 2013).

It must be understood that hundreds of suppliers are delivering just-in-sequence to the BES manufacturing plant. If mistake occurs anywhere in these deliveries and BES is informed before the cars are put on the TRIM assembly line, sequence can be modified accordingly so that the line does not have to be stopped. Therefore, short term demand is volatile as these modifications sometimes happen shortly before the final sequence is created.

4.3.1.2. FGS consignment warehouses to enhance sequencing

Consignment stock warehouse means that even though it is located in the supplier park, stock belongs to tier 1 suppliers. The point where the stock is passed on to the BES accounts is when the car is finished and leaves the production line.

It has many advantages for BES. This way it is by accounts operating with fewer inventories. It also has a positive impact on their cash flow as they receive invoices for delivered parts later. On the other hand it has opposite impact on the tier 1 suppliers. However, for example DISS is using the same method with its suppliers. This way value of inventory in the entire supply chain is lower. It is so because if upstream manufacturer supplies to its customer downstream it will always sell the stock for more, than what is the value of stock in their warehouse. Therefore the same stock is worth more as we move downstream the supply chain. From the FGS warehouse parts are pulled to the assembly line with kanban trays in sequence.

DISS is supplying 31300-A6900 product just-in-sequence together with other bundles. However DISS is not located inside the supplier park. Therefore they use FGS consignment warehouse to organise the sequencing. DISS supplies in batches of eighty 31300-A6900 bundles to the FGS warehouse where they configure the sequence and delivery it to the assembly line. FGS warehouse is operated by DISS´s employees and represent crucial element of just-in-sequence deliveries for them, as their production line is located 40 kilometres away.

4.3.1.3. Operating FGS warehouse

DISS delivers their 31300-A6900 product on trays with batch size of eighty bundles to the FGS consignment warehouse drawn on BES´s Value Stream Map in the blue area.

In these external warehouses products are put into sequence on the kanban trays together with other bundles according to the TRIM line sequence.

There are 3 kanban trays used between the FGS warehouse and the assembly line. In the figure 23 you can see the layout of a part of the assembly line and the FGS warehouse. A thick blue line represents the TRIM assembly line with blue squares which are individual workshops on the line. The yellow square highlights the workshop where DISS´s break and fuel bundles are assembled on cars. It is called “Chassis” workshop.

As can be seen in the picture two kanban trays are located by the chassis workshop. One is being used by the assembly line operator, the second is filled according to the upcoming sequence and is waiting to be used and the third is being filled according to the planned sequence in FGS.

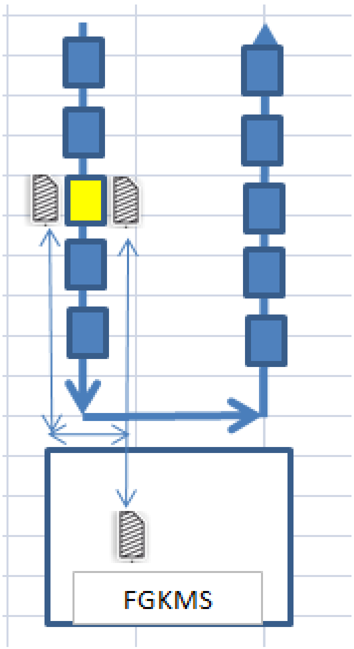


Figure 4-8 Assambly line and FGS Warehouse Layout

An electric trolley is moving trays between the workshop and FGS in approximately 40 minute intervals, always keeping one extra filled tray at the workshop.

In FGS there are 3 employees of DISS. One is responsible for quality and two for logistic processes. They are offloading full trays from the trucks which brings them from the DISS´s plant. The empty truck is refilled with empty trays which are taken back to the plant. The employees are also sequencing products onto the kanban trays which are send to the production line workshop from FGS warehouse.

4.3.1.4. Right sequencing to improve capacity

Ever since 2006 when BES produced its first car it is gradually increasing production. It is possible mainly by increasing the number of shifts, working days and lowering the cycle time. Currently the cycle time is 29 seconds which enables car production of 14860 cars a week with 5 working days and 3 shifts.

Decreasing cycle time can be done by improving assembly processes but also by improving sequencing. Assembling some car modifications are less time consuming than the others. One of the rules that BES uses, is that no more than 2 SL car types, which are relatively complex models, can follow one after the other because operators at some workshops would simply not be able to assemble two SL cars in 58 seconds.

Therefore, sequencing structurally less complex models after more complex ones can improve cycle time. However it can be in contrast with BES flexibility. Balancing between these two factors is crucial for achieving an effective and an agile production. Software is constantly calculating the optimal sequence by sophisticated algorithms under the given constraints.

Such enhancements are conditional to reliable supply chain which is improving every year. Sequencing is a big challenge for the supply chain however it dramatically improves agility of the manufacturing plants.

4.3.1.5. Safety stock as a must for just-in-sequence

In the FGS warehouse there is safety stock that is necessary to support sensitive just-in-sequence deliveries of suppliers outside the supplier park in the case of emergency. However products may not stay there for more than 3 weeks according to the quality requirements. Within this period of time, stock must be used and replenished.

During winter time there is more safety stock required due to bad weather conditions, which may paralyze traffic. That is another disadvantage of suppliers located outside the supplier park. However it would not be possible to store this extra safety stock to already packed FGS warehouse, therefore DISS is renting another external warehouse close to the supplier park. There is 1 extra day of inventory held during winter time.

This safety stock must also be used within 3 weeks. Therefore during the winter time trucks are often reloaded at this warehouse before reaching FGS warehouse. They simply change trays with the “fresh” products for the one that have been in the winter external warehouse for some time.

4.3.2. Red Area - Tier 1 Supplier

4.3.2.1. Timed deliveries as crucial ingredient of just-in-sequence

Logistics is an important aspect, especially for suppliers that are located outside the supplier park. Faulty deliveries are just not acceptable for just-in-sequence and improving reliability of deliveries and proximity of suppliers lead to decrease in finished goods inventory. DISS is located 40 minutes from BES by truck and uses an external haulier to cover the transports.

As BES pulls parts from the FGS warehouse, it is supplied from the DISS´s production plant by 6 deliveries every day. These are loaded at the DISS´s distribution at 07:00, 10:00, 15:00, 19:00, 23:00 and 02:30 by the external haulier. There are up to 8 trays in one delivery.

The brake and fuel bundles are relatively light but space consuming products. The haulier is therefore using a light, rigid truck with a trailer which can load up to 8 trays while having little fuel consumption. This truck has curtain sides so it is possible to load and offload from sides.

The haulier is running 2 shifts to ensure 6 smooth deliveries every 24 hours. It is important to synchronize the delivery windows with driver´s working hours which have to obey AETR. AETR is European agreement concerning the work of crews of vehicle engaged in the international road transport. In the figure 24 you can see two drivers shift pattern. First driver is marked by black and second by red line.

The first shift driver is starting at 6:00 at the haulier´s base driving to DISS so that he arrives before 7:00 for the first loading. The driver loads within an hour and then must be able to reach BES, offload and come back within 2 hours. Between the second and the third loading, the driver must take compulsory 45 minutes break before loading the third load. There is 1 hour buffer time before the third load is due at 15:00. After offloading the third load the driver must swap at the haulier´s base with the second driver. Again there is one hour buffer time. The second driver must drive to DISS to load the fourth load at 19:00. Within two hours the second driver is offloaded and back at DISS site. He must have a 45 minute break and load the fifth load. Again within two hours he loads the sixth load and drives to the haulier´s site to swap with the first driver. There is 2 hours buffer time at this point.

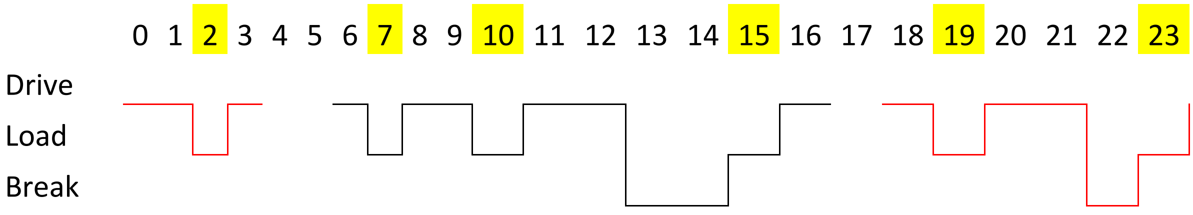


Figure 4-9 Driver´s working pattern

This timing is crucial and the haulier keeps spare drivers and trucks nearby in the case something goes wrong. That is why the location of the haulier is also important. Therefore a haulier that is close and has the capacity to handle faults must be selected.

4.3.2.2. Batch production for just-in-sequence

Material flow at the DISS´s site consists of 8 steps. Finished goods are stored in the distribution centre. Here products are stored on trays ready to be loaded on trucks. Each tray is filled with only one product type and they are put into sequence later in the FGS consignment warehouse as stated earlier.

Figure 4-10 Feeled tray in the finished goods warehouse

Trays are pushed to the finished goods warehouse from assembly tables. There are 80 assembly tables. Each is constructed to assemble specific brake and fuel bundle. Two of them are assigned to 31300-A6900 bundles. At this point two metal and three plastic pipes are put together on holders and they are tested for potential leakages. They can be operated by 1 or 2 operators per table. For our measured production of 6934 of 31300-A6900 products per month two operators per table were needed. According to time standards two operators can double the production at the assembly table. However, no more than two operators are able to work at one assembly table. At this point a brake and fuel bundle is also checked. Using air pressure, operators are testing whether the bundle does not have any leaks. Up to this point operators are working with a batch size of 100 metal pipes. After the assembly table products are put on trays with a batch size of 80 break and fuel bundles per tray. Break and fuel bundle can be illustrated in the figure below.

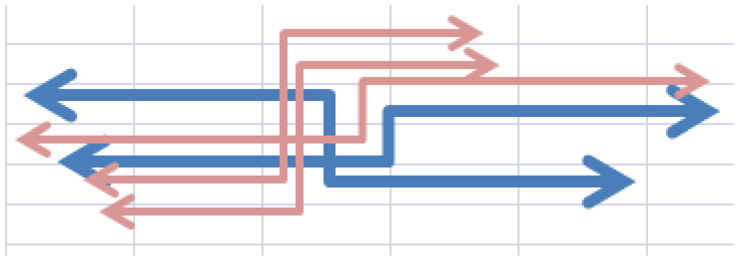


Figure 4-11 Finished break and fuel bundle

The production plant works on a combination of a push and a pull system. Each production process has its own plan for each day which is typical for the push system; however sequence in which they produce different products is based on communication of operators which are pulling the materials from previous processes. There will be more explanation given to this mater later on in this thesis. Assembly table operators are pulling the material from power bender. There are two types of bending: Manual and Automatic. As 58736-A6300 is a fast moving part, automatic power bender is used. It is fully automated operation where the metal pipe is bent to form a specific shape for the brake and fuel bundle to fit perfectly on a car´s chassis. Usually the operator of the previous process brings and loads the automatic bender with straight pipes. The operator from following process comes and collects the bent pipes. Affect of power bending is illustrated in the figure below.

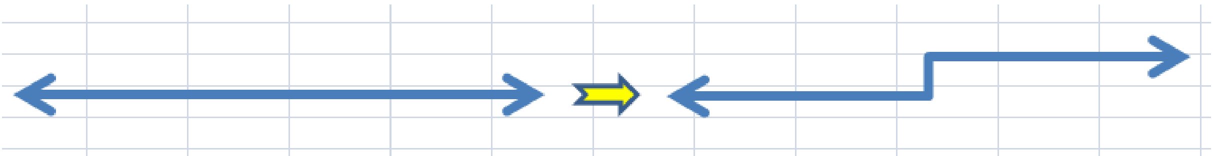


Figure 4-12 Affect of power bending

A process before the power bending is shrink oven. Shrink oven is used to shrink a santoprene rubber protection which is installed on the metal pipes. This protection protects the metal pipes from scratches. It can also be operated by one or two operators, where in case of two operators; the production is doubled. As there are only two shrink ovens for dozens of part numbers, operators must adjust holders for each batch of 100 or 50 metal pipes that they pull from pressing operation.

Pressing is a relatively quick operation. Ends of metal pipes are equipped with nuts so that they can be installed on cars. Figure below shows the ends of a pipe after nuts are installed at the pressing operation. In the figure 4.13, the ends are represented with arrows. This is a point where products are being connected with the cars and it is a very sensitive operation. Unrecorded defects would result in fuel and brake fluid leakages. There are 9 pressing machines. Each is set for specific metal pipe diameter. One machine can be operated with maximum of 1 operator.

Figure 4-13 Pipe´s end after pressing

Pressing is the most defect sensitive operation. It has the highest defect ratio of 0.66%. It is also working with the metal pipes ends. Both ends must be milled to create smooth and regular surface for the pressing machines. This smoothed surface of the pipes can be seen in the figure below. There are 6 milling machines and each is set for a specific metal pipe diameter. One operator is operating one milling machine.

Figure 4-14 Smoothed surface after milling

For milling, material is pulled in batches of 100 metal pipes from the cutting t-drill. At this point large metal pipe coils, from the REVE supplier are installed on the cutting machine which is cutting predefined metal pipe lengths. These are put into batches of 100 metal pipes and placed into the supermarket which can be seen in the figure below. There are two cutting t-drill machines and each one is operated by one operator.

Figure 4-15 Supermarket at the cutting operation

4.3.2.3. *Raw materials consignment warehouse*

There are only few diameters of the metal pipes that are used. These metal pipes are wounded into metal coils, and are pulled from raw materials consignment warehouse illustrated below.

Figure 4-16 Raw materials warehouse

Metal pipes are delivered from the REVE supplier located in Germany twice per week. REVE is constantly checking inventory levels so that it is never lower than 1.9 days and higher than 8 days. Due to the low number of stock keeping units and the batch production, just-in-sequence deliveries are no more relevant further upstream the supply chain.

4.3.3. Green Area – Tier 2 supplier

4.3.3.1. *Logistics*

DISS has one of the steadiest demands out of all REVE´s customers. Usually they demand 220 km of 4mm metal pipe every week. To fulfil this requirement with relatively low inventory, REVE is servicing their consignment warehouse at the DISS´s site by weekly truck deliveries from distribution department.

One truck can load up to 190 km of metal pipe per one load. Therefore a minimum of two deliveries are required. With two deliveries per week, there is spare capacity of 160 kilometres per week in the trucks. Therefore, each delivery is also loaded with 80 extra km of the metal pipe to be delivered to another customer in Poland. This way transportation costs are optimized, while two deliveries also result in lower inventory. Due to the fact that REVE only produces 4mm metal pipes and DISS is producing in batches, sequencing would not make sense.

4.3.3.2. Production plant

Its production of metal pipes with diameter of 4mm consists of two main process steps. The first is production of raw pipes at a CBL lines. All together REVE has 4 CBL lines with total capacity of 320 km per day. 3 operators per shift work at each line. This line has continuous production flow from raw metal strip coils to raw pipe coils. Therefore there is no work in process inventory between these steps.

After the raw pipe coils are produced the surface must be smoothed and by electrolyses, covered with aluminium and rubber.

For this ACC lines are used. There are 2 ACC lines each with production of 180 km per day. All together they can produce 360 km per day. Similarly to the CBL line, ACC line is a continuous, automated production with no work in process inventory.

There is a difference in production capacity of 40 km between the CBL and ACC line. In peak production this difference can be covered by purchases of raw metal pipes from another supplier.

Finished metal pipes are pushed to the distribution department from the ACC line. At the distribution they are stored for upcoming deliveries. Pipes are wounded onto special metal pallets. One pallet can take from 7.5 to 8.5 km of the pipe. Inventory of finished goods at both REVE and DISS site must be between 1.9 and 8 days. Usually this can be achieved with average inventory of around 6 days. As inventory is decreasing at the consignment warehouse at DISS, the one at REVE is steadily increasing. It must be sure that inventory at DISS will never come to the 0 before the next delivery arrives.

The ACC line is pulling raw metal pipes from the CBL line in the same batches of 7.5 – 8.5 km of pipe wounded on the same special pallets. It is also pulling aluminium and rubber from the raw materials warehouse. It takes 1.01 second to produce 4.212 metres of metal pipe. This length is important as that is the length of our measured part of DISS´s production.

There are 4 CBL lines which are operated with 12 people per shift. CBL lines are pulling materials from the raw material warehouse which is located just between the CBL and ACC lines as both CBL and ACC lines use materials from this warehouse. From raw materials it processes raw pipes by banding and welding. They are also wounded in batches of 7.5 – 8.5 km per pallet. 4.212 metres of pipe is processed in 1.14 seconds.

4.4. Information flow

Flows of information between the suppliers ensure that each supplier knows how much and when to make their products. Similarly flow of information within the company ensure that each process manager knows when and what to produce.

4.4.1. Car manufacturer

BES is using specialized software to sequence the production. The software creates sequences for all three main parts of BES production – Welding shop, Coating shop and Assembly line.

The sequence is shared with their ERP software, which has an online platform available for suppliers. From this platform suppliers can obtain 90 days of planned production. This plan represents both forecasts and orders. However, as mentioned earlier, plans are changing several times during the day and the shared plans are not binding for BES. Therefore it must be constantly checked by the suppliers.

The production sequence can be modified before each part of BES production plant – Welding Shop, Coating Shop and TRIM assembly line. However after the Coating shop, when cars are put on the TRIM assembly line the sequence is final for the suppliers. This is when information about the sequence is sent electronically to the FGS warehouse. It is approximately 90 minutes before the products must be at the assembly line. Here this information is displayed on large screens where the warehouse operators can easily see it.

4.4.2. DISS supplier

4.4.2.1. Sequencing

As the FGS warehouse operator puts products into sequence on the kanban tray for the assembly line, he is also scanning Leak Test Label codes with a bar code reader. Each product has its own Leak Test Label code which is represented by a bar code attached to the products. This code is unique for each piece of production and is attached to the product at the assembly table after a leak test. The operator is required to scan every product after he places them on the kanban tray. If any variety between the sequences displayed on the screens and the operator physical putting products on the tray occurs, the screens starts to flash in red and make an alarm noise. This ensures right sequencing and eliminates human errors.

By scanning the products Leak Test Label codes are shared online with the BES´s ERP software. This ERP software automatically assigns each Leak Test Label code to the specific serial number of a car. At this point every car that is about to be produced already has the specific parts assigned.

4.4.2.2. Production planning

MRP department of DISS has its own login details for the BES´s ERP software. At the online platform they can see all the data relevant for their planning. This data can be downloaded in different formats so that the supplier can work with them. DISS uses xlxs format to work with the data in excel. Table below shows raw data of one week of planed production in xlxs format. 58736-A6900 break and fuel bundles are named Z4 in BES´s ERP portal.

	6.2	6.3	6.4	6.5	6.6
B01	62	106	80	71	57
B02	15	60	31	37	52
BR3	24	1	16	20	20
Z1	19	46	36	36	39
Z2	59	80	115	106	98
Z3	177	115	98	93	61
Z4	170	159	176	192	194
Z5	86	49	62	48	72
Z6	31	11	17	23	34

Figure 4-17 Raw data

DISS is not using any Electronic Data Interchange (EDI) platform to transform the data. Instead the data are manual copied into planning excel templates by the logistic department. The excel templates highlights, when DISS is going to run out of stock at FGS warehouse. The one that are going to last the shortest are logically going to be refilled by the first deliveries of the day and vice-versa. Each of the six deliveries per day is planned this way using EXCEL. Planning is starting every day at 08:30 in the morning for 10:00, 15:00, 19:00, 23:00, 02:30 and 07:00 delivery. Before every truck is loaded the ERP portal is checked as the plan may change several times throughout the day. Deliveries are instantly modified according to the changes in the ERP portal. Sometimes these plans changes by 10-15% especially at 7:00 and 15:00.

By 9 AM the delivery plan is sent to the production department. They import the delivery plan into a production plan template which redistributes work for each shift according to the finished goods inventory at the distribution. Similarly to the logic described earlier, goods that are going to last the shortest at the distribution are planned for the earlier shifts.

In the production plan template, the assembly operation is authoritative for the other production steps. In the Value Stream Map, this is marked by the thick blue arrow aiming to the assembly process box. After a plan is made by the production department, daily schedules are sent to all process steps so that everybody knows what should be produced. The order in which the parts should be produced is planned by a pull factor of following operation. Starting from the assembly tables, material is pulled from previous operations. Except the cutting t-drill there are no supermarkets to pull the materials from as it would increase amount of inventory rapidly. Sufficient work in process inventory at each stage of production is managed by operators which are working close by. Proximity enables instant communication about upcoming material demand and work in process inventory control.

Each batch of work in process inventory has its own LOT number which is registered by DISS´s ERP software. After finishing each batch, operators are scanning the bar codes at each process step. This way company can track work in process inventory, process times and when, by whom and on which machine the batch was manufactured. LOT numbers are also assigned to the raw materials and finished goods. Each LOT number is connected with the Leak Test Label code. This way DISS has an outlook over the entire material flow from the raw materials to the BES´s production line.

4.4.3. REVE supplier

In fact, due to the very high demand, REVE´s production plant is constantly producing. REVE is allocating their production to its customers to keep the minimum and maximum inventory levels. If inventory levels of REVE´s consignment warehouses fall dangerously low, overtimes and production during weekends take place. Redistribution of production to the customers is calculated by EXCEL spreadsheets.

Suppliers of REVE also have a consignment warehouse at REVE´s site. Similarly to REVE they are tracking their inventory levels of raw materials such as metal strip coils, aluminium and rubber and replenishing them on weekly basis to always meet minimum and maximum inventory requirements. Mutual weekly e-mail communication confirms orders for the next week.

5. Analyses

5.1. Introduction

This section of the thesis will analyze a timeline, push and pull factors and TAKT times in the measured supply chain to try to identify impacts of just-in-sequence deliveries on the measured supply chain.

Timeline shows proportion of contribution of each entity to the overall value adding and non-value adding time. The analyses will try to compare non-value adding times among the entities with respect to their contribution to the value adding times. By doing so, it will try to highlight impacts of proximity and just-in-sequence deliveries on the whole supply chain.

Pull factor is crucial for just-in-sequence deliveries and lean manufacturing. By analysing what factors are used throughout the supply chain, the analyses tries to conclude whether the sequenced pull of the car manufacturer has an impact on the wider supply chain.

Aligning TAKT times vertically among the suppliers is essential for a lean supply chain. In this part, analyses will compare TAKT times among three measured suppliers from different TIERs to analyse possibilities of TAKT time alignment among them. By the analyses one can see the impact of car manufacturer to the wider supply chain.

5.2. Inventory

Inventory is the most used indicator to measure efficiency by the companies in the measured supply chain. Therefore, supply chain managers are being encouraged to lower them. With the measurements which are shown in the cells between each process box we can summarize the current state of the value stream. By adding up the times of all value adding and non-value adding activities displayed on the timeline we can measure the performance of the value stream.

In the measured supply chain of the car manufacturer, tier 1 and tier 2 supplier it takes 11.11 days to install a break and fuel bundle on a car in the measured supply chain (5 days of inventory of the raw materials at REVE that belongs to the tier 3 supplier is not included). From this time only 0.006 days (522.19 seconds) is value adding time which is the time when the products gain value that customers are willing to pay for. It means that 99.95% of all the time in the measured supply chain product is just being stored or transported to another plant or operation.

In the table bellow proportion of value adding and non-value adding time between BES, DISS and REVE can be seen. BES has value adding time of 0 sec. It is so, because the measured supply chain ends at the point where products are delivered to the assembly line. Storing, sequencing and transporting of goods at the BES´s site are all non-value adding activities.

	Value Adding Time		Non-Value Adding Time	
	Absolute	Relative	Absolute	Relative
BES	0 sec	0%	1.57 days	16%
DISS	520.04 sec	99.6%	2.88 days	21%
REVE	2.15 sec	0.4%	7 days	63%

Figure 5-1 VAT vs. NVAT

From the table it is clear, that REVE contributes to the largest proportion of non-value adding time even though they contribute to the value adding time just by 0.4%. DISS which is supplying 80 product types and its production includes 99.6% of the value adding time contributes to the overall inventory just by 21% at their site and 16% at BES´s site. On the other hand REVE which produces just one product – 4mm metal pipes, contributes to the overall supply chain inventory by 63%. It is caused mainly by the distance and frequency of deliveries. In comparison to DISS, which is located 40km from its customer and delivers 6 times a day, REVE is located around 1000km away and delivers 2 times a week. Here, the positive impact of just-in-time sequenced deliveries on inventory levels between BES and DISS can be seen.

5.3. Push vs. Pull

By understanding how the plans for each individual production process are made, we can distinguish between push and pull factors between production processes. In push each process produce according to its own production plan and do not consider what downstream processes require. It often results in large inventories as the demand of the downstream process can change and differ from the plans (Rother, 2009).

BES is pulling the materials from its suppliers and from its own warehouse according to the current demand on the TRIM assembly line with kanban trays. Some of these deliveries, such as from DISS, are sequenced. We already discussed the advantages that it has on BES manufacturing plant and its lean manufacturing.

On the other hand, DISS is using both push and pull factors in its production. Due to complexity of the production, pure pull would not be rational as many stock keeping units would have to be placed in supermarkets between each process step. This would ironically result in higher work in process inventory. Pure push would also not be efficient because without consideration of either demand of downstream process, individual processes could easily run out of material or could be over stocked.

Therefore, a hybrid that tries to utilize on both individual plans, which signalize what parts are going to be produced for each day, and pull represented by communication of operators, is used. The communication indicates what material is about to be missing for the downstream process the first. Furthermore, individual plans are important so that operators always know what to produce even though there is neither actual demand from downstream process, nor an extra operator needed at any different process step. For functionality of this hybrid model proximity of operators and their knowledge of working at more processes are essential. Proximity is important for constant communication between processes. Operators must also know how to operate different machines to ensure flexibility of production at each process step. In other words, if material is missing at a downstream process, the operator from the downstream process simply moves upstream to enhance replenishment of the missing part.

It would be essential to move towards pull system. However in order for pure pull to be rational, number of stock keeping units would have to be lowered.

This could be done by further involvement of DISS in product design and modular production that have been explained earlier in this thesis.

REVE is pulling material from the warehouses which are maintained by its suppliers at agreed minimum and maximal level. All the production is then pushed to the distribution centre from where it’s redistributed to the customers, according to minimal and maximal inventory requirements.

5.4. TAKT Time of the supply chain

As already mentioned the car manufacturer has the main power over the supply chain. BES´s cycle time is 29 seconds. DISS´s cycle time is derived from the 29 seconds as BES is their only customer. So we could say that TAKT time for the break and fuel bundle production line is 29 seconds. However, break and fuel bundle production line cannot be clearly identified as other product lines such as hydraulic pipes are also produced on the same machines (cutting, milling, pressing, ...). Therefore, the line must produce more products, than the number of cars produced by BES. If we exclude the smallest products DISS is producing on average 5400 different bundles per day. This gives a TAKT time of 15 seconds.

Figure below contains cycle times. In order to compare the cycle times with the calculated TAKT time, number of workers operating more machines must be considered. For example there are two operators that are milling the pipes. That means, that even though the cycle time of milling is 11.08 seconds two operators are able to mill one pipe in 5,5 seconds. However, this number must be further multiplied by 2 as there are 2 metal pipes produced for one break and fuel bundle assembled.

	Cycle Time	# of workers	Cycle Time/#of workers * 2
Cutting T-Drill	18	2	18
Milling	11.08	2	11.08
Pressing	16.16	3	10.8
Shrink oven	16.76	3	11.2
Bending	74.04	12	12.3
Assembly	384	32	12

Figure 5-2 Cycle Times

According to the calculation above, cutting t-drill is a bottleneck of the production with an operation cycle time of 18 seconds to produce two metal pipes. This calculation can be proven by experiences of the DISS´s managers, which often must plan overtimes for cutting operation. Therefore, increasing capacity of the cutting t-drill would increase the capacity of the whole production.

REVE has a maximum production of 2520km of metal pipe per week. In other words, it produces 1km of metal pipe in 4 minutes. DISS is ordering on average 220km of 4mm metal pipe from REVE. Therefore, DISS forms 8.7% of REVE´s maximal production. In order to calculate REVE´s TAKT time, aggregate demand would have to be known. However, it can be concluded that DISS contributes only to 8.7% of REVE´s production.

5.5. Conclusion

Even though DISS is able to achieve remarkable results of an inventory optimization due to use of just-in-sequence deliveries, this form of delivery is not used only between DISS and BES. Proximity which is so important for the tier 1 suppliers to manage high standard of just-in-sequence deliveries, is no more prevalent at the second tier. Suppliers of DISS are located further away than suppliers of BES. Therefore, frequency of deliveries is lower due to the higher transportation costs and inventory must be held at higher levels. It can be observed, that as complexity of production decreases, economy of scale start to be prevalent and distances between entities longer. In other words, it would not be rational to built production plant of 4mm metal pipes just for one customer with demand such as DISS.

Similarly to just-in-sequence deliveries organization of production of REVE seems to be independent from the car manufacturer. However, if DISS would be operating sequenced production impact of sequenced pull of BES could be higher upstream the supply chain.

A TAKT time is a good indicator of integration in the supply chain. It can be seen that DISS´s TAKT time is derived from BES´s cycle time. However, it cannot be observed in REVE that have more customers.

6. Conclusion

This research conducted another case study to enhance practical knowledge already gained in the field of just-in-sequence deliveries. Furthermore, it gave a wider supply chain point of view which has been missing.

Just-in-sequence deliveries have significant impact on the tier 1 supplier. Car manufacturer is for many tier 1 suppliers the only customer. Therefore, their integration into car manufacturers processes is very high. Car manufacturer usually requires tier 1 suppliers to be located nearby to enable just-in-time and just-in-sequence deliveries. Result of this effort can be seen at the timeline of the measured supply chain. Despite the complexity of product portfolio and production process, tier 1 supplier is able to achieve relatively low inventory levels and keeps non-value adding times down. In the measured supply chain the tier 2 supplier contributed to the largest proportion of inventory levels, despite the fact that it supplies just one product with very stable demand.

Pull factor is very dominant at the assembly line. However, going upstream the supply chain pull is either mixed with some push practices or abounded. At the 1^{st} tier level it is due to complexity of production. Further development of modular production of the car manufacturer and suppliers´ involvement in product design could reduce complexity of product portfolio which would result in lower number of work in process part numbers. This would enable the tier 1 supplier to adapt pure pull and further decrease inventory. With lower amount of work in process part numbers and higher proximity the tier 1 supplier could also adapt sequenced production to fully utilize on benefits of just-in-sequence deliveries.

The car manufacturer cycle time also has a significant influence on the tier 1 supplier. Its TAKT is basically derived from their cycle time. However, it is not equal to the cycle time of BES as they are producing more than 1 product for each car. REVE´s TAKT is derived from many customers and DISS contribute to only 8.7% of its production.

It can be concluded that REVE – the tier 2 supplier has not been affected by just-in-sequence deliveries at the tier 1 level and is much less affected by BES. First of all there is no evidence that production or logistic processes of REVE would be different in relationship to DISS, than it would be to any other customer. Secondly, it can be noticed that demand for extremely lean practices of frequent, in time and in sequence deliveries of BES are less dominant between 1st and 2nd tier. Due to the mass production of very narrow product portfolio, economy of scale utilizing on larger demands from more customers is dominant at this point.

7. Limitations and future research

It must be underlined that the research considered only one supply chain that consists of BES, DISS and REVE. Therefore, any conclusions of the research are subjective to the specific example. Other companies supplying for the same car manufacturer can perform differently. DISS is also producing in batches and uses warehouse in the supplier park to sequence the final delivery to the assembly line. As mentioned in the literature review of this thesis, there are two more different ways to sequence deliveries. For the future research it would be essential to examine suppliers that operate sequenced production. Sequenced production could bring challenges connected to the sequenced deliveries further upstream the supply chain.

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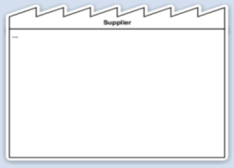
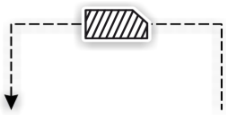
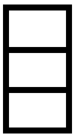
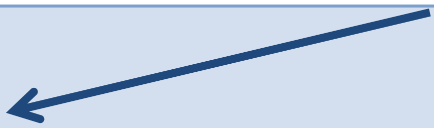
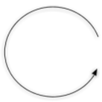
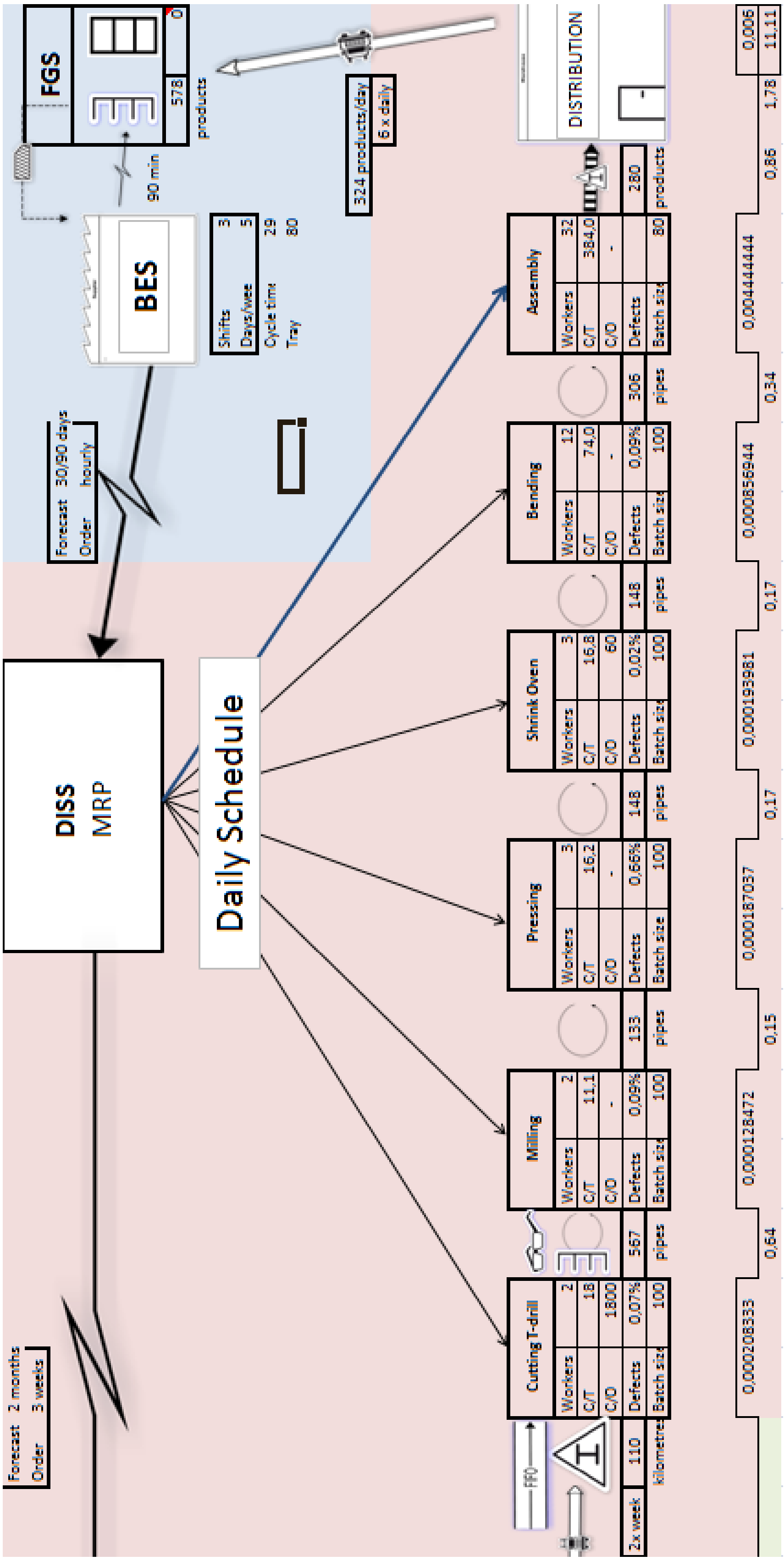
Appendices

Appendix A – Icons used for value stream mapping. (Jones & Womack, 2002)

Icon	Meaning
	Entity of a supply chain
	Kanban batch trays
	Supermarket
	Safety stock
	Deliveries using road transportation
	Inventory
	Information flow
	Electronic information flow
	Push factor
	Pull factor
	“Go see” scheduling

Appendix B – Current Value Stream Map of the measured supply chain (Part A)



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Appendix C - Current Value Stream Map of the measured supply chain (Part B)