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Supply chain challenges and how to manage them

AGCO Power: A Logistics perspective

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Abstract

AGCO Power is a manufacturer of engines, gearwheels, gearboxes and engine spare parts to the world's leading manufacturers of tractors and other agricultural machinery. In order to be successful in today's global market environment, we must satisfy and exceed our customer expectations on all fronts. We need deliver products our customers want, fast and with competitive prices. Our supply chains become more and more complex and at the same time continuous cost savings are required to maintain competitiveness. Supply chain management is more vital today than ever before and we must design our supply chains to manage all challenges it faces but also gain competitive edge by intelligent supply chain design.

Research focused on underlying the current challenges for our supply chain management and what are the factors that drive these challenges. How are we able to manage these challenges and at the same time visualize, improve and optimize our supply chain management processes. Research was conducted by qualitative - and quantitative measures through interviews and company data analyses. With interviews we brought up challenges that our logistics experts were faced with in their day to day work and with data analyses we studied the reasons behind these challenges.

We managed to disclose the supply chain challenge drivers and were able to bring forward solutions to improve our entire supply chain environment. With more intelligent strategy for our demand management and inventory we are able to stabilize demand and reduce complexity throughout the supply chain. We also created a tool to visualize and manage our supply chain management processes, create targets for material inventory and in return allow us to achieve better service levels and less disruptions for our production.

Keywords/tags (subjects)
Supply chain management, Demand variability, PFEP

Miscellaneous (Confidential information)

Contents

Figures

Tables

1 Company overview and supply chain design

AGCO Power is a manufacturer of engines, gearwheels and gearboxes, engine spare parts and diesel generators. Our core business is to create diesel engines for many of the world's leading manufacturers of tractors and other farm machinery. It is also the engine of choice for a large number of other applications around the world. AGCO Power is part of AGCO corporation which is the world's third largest developer and manufacturer of agricultural machinery. AGCO core brands include such agricultural machinery manufacturers as Fendt, Massey Ferguson, Challenger, GSI and Valtra. AGCO has 9000 dealers in 140 countries around the world and AGCO Power supplies currently more than 50 percent of the engines used in AGCO products worldwide. AGCO Power has four manufacturing sites globally and for which the largest manufacturing site and company headquarter is located in Linnavuori Finland. Company turnover in 2015 was approximately 300 million euros and sold close to 40 000 diesel engines (AGCO Power, 2017).

AGCO Power company products can be segmented into four sectors: engine spare parts, engines, gears and diesel generators. Our core product is diesel engine and engines are manufactured mainly for our internal customers, AGCO corporation agricultural machinery manufacturers. Diesel engines covered 82 percent of AGCO Powers total sales in 2015. Spare parts are delivered straight to the farm machinery end customers and dealers. Gear products are mainly sold to the same internal customers as engines with exception of few small customers outside AGCO corporation. Our goal is to supply more than 90 percent of total engines used in AGCO farm equipment's (AGCO Power, 2017).

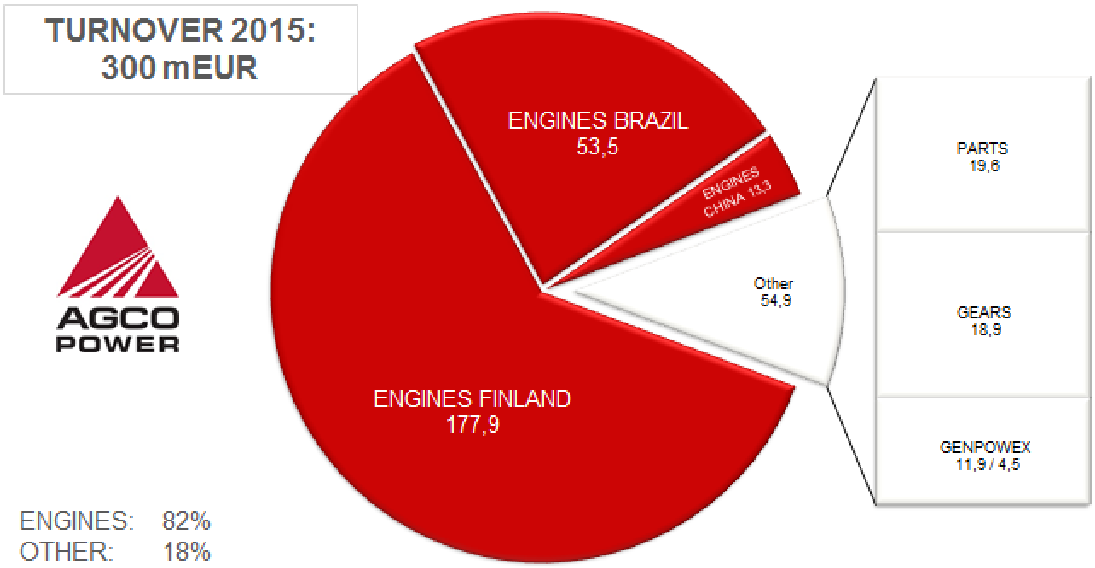

Figure 1: AGCO Power sales and operations in 2015.

Figure 2: AGCO Power customer portfolio.

1.1 Channels on creating value

To better understand the supply chain structure it is important to highlight how AGCO Power creates value for its customers and how we aim to service our customers in the best possible way.

1.1.1 AGCO Power creates high valued products through innovation.

Product development is the number one factor to our success in the global market for diesel engines. We create fuel efficient solutions that deliver maximum power aligned with our customer needs. Our customers are the driving force in our product development and that level of collaboration is possible in our internal customer relationships. Our customers are offering us knowledge and information for developing products tailored according to our customer needs.

To our customers we offer a strategic partnership and resources for creating the best possible engine solutions for their agricultural machinery and thus enable strong commitment to our products (AGCO Power, 2017).

1.1.2 Service through spare parts and product maintenance.

Our product life cycle does not finish in the sales stage. We also offer service for our customers and their customers by maintaining our products long after they have been sold. Aftermarket offers spare parts for our engines and maintenance work and is also one of the most lucrative business areas in our company.

1.1.3 Flexibility in customer service

Our main objective in customer service is to create products for our customers demand. In the agricultural machinery market demand is fluctuating and it is difficult to predict. Farmers and dealers want products fast and with decreasing lead times. We can satisfy this demand by creating a flexible supply chain and adjusting our company production to meet the customers demand. By achieving an increased customer satisfaction through high delivery performance and flexibility we ensure our place as a strategic partner for AGCO corporation.

1.2 Customer relationships, - service and supply chain overview

For AGCO Power long-lasting partnerships are the key factor for success. Our product is tailored in conjunction with our customers and product life cycles are fairly long. We establish strategic partnerships with all our customers in order to ensure our products are preferred to our customers and used for long periods of time. New customer relationships are difficult to establish and require vast investments. Our customer segment consists of many customers outside and within our organization and our business strategy is to grow our market share in all segments. Our focus for future is to create long-lasting partnerships with our current customers and create new valuable relationships through sales.

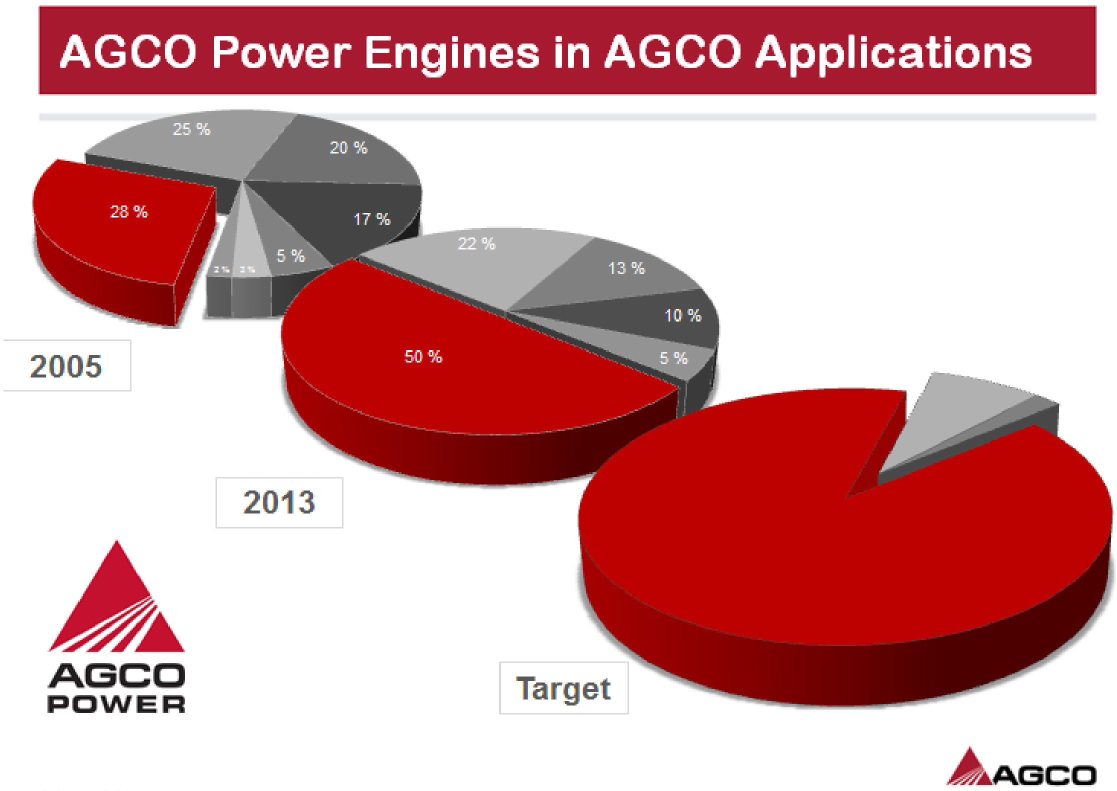

Figure 3: AGCO Power engines in AGCO applications.

Along with best in class technical solutions we drive to offer our customers value through continuously improving customer service. With flexible lead times and - production capacity we are able to react to changing customer demands fast. This of course requires a high efficiency from our supply chain management and design. With lead times as low as two weeks and supply lead times of engine components up to 16 weeks, our sales and operation planning as well as purchasing must function in seamless co-operation and efficiency. With a global purchasing network and a global distribution network supply chain management holds a significant potential for success.

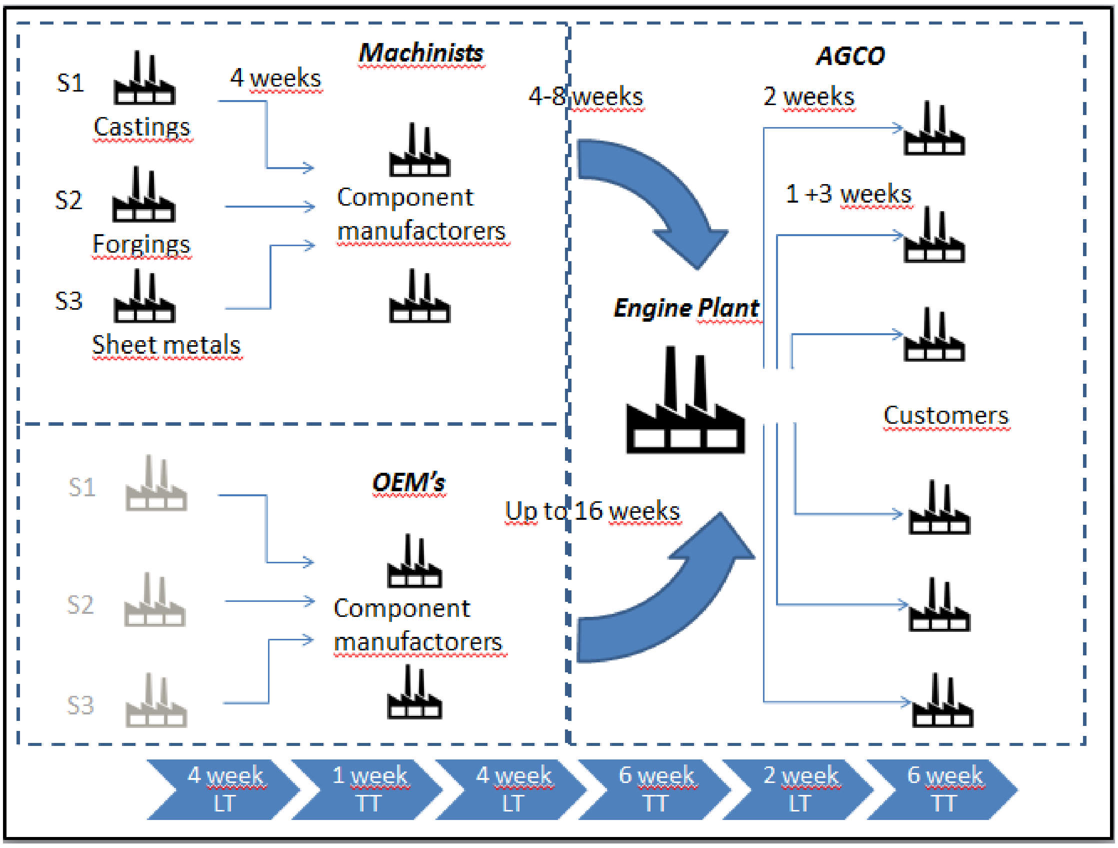

Figure 4: Supply chain lead time.

1.3 Revenue streams

Our company is creating value by selling and servicing diesel engines, gears and diesel generators. Very little of the components used to assemble engines are created in our company. Most of the components used are purchased from our suppliers and then delivered to our company for engine assembly. We want to offer high valued solutions to our customers but also with competitive prices. Since we are part of the same corporation with the majority of our customers, their success is also our success. In order to create value for us as a company, we must create our products as efficiently as possible. AGCO Power sets the company targets in optimizing efficiency in all levels of its operations. Currently the biggest opportunity in creating profit is to lower the expenses in our supply chain. We must purchase quality components with decreased unit prices. This is possible with combined purchasing power of us and our internal customers. With combined volumes and supply chain networks we are able to acquire our materials with much more lower costs than our competitors. This is a tremendous advantage for our company.

1.4 Key resources and macro driving forces

Our company's biggest asset is our engineers and professionals that create the high tech products we offer for our customers and these professionals also make sure our operations are as efficient as they can be.

Our company is mainly influenced by agricultural markets and if producers aren't making profits due to lowered product pricing or low growth yields, producers aren't investing in new machinery. Seasonal fluctuations can be high due to global market downturns, but the most significant reason for seasonality in our sales comes from agricultural seasons and the investment requirements for machinery. On top of that legislation also has a major role in our product offering. Due to emission legislation we are only allowed to produce certain emission level engines to certain markets. Globally Europe and North America have the most strict emission level limits and these levels are upgraded in every five years or so. Especially emission level legislation can be seen in our business strategy decision making. When lower level emission standards are still valid, but next year emission level is upgraded we as engine manufacturer produce much more than our customers actually demand. These engines are created to stock and sold to our customers after emission level legislation has changed. These stock engines can't be produced after legislation has passed, but can be used for our customer products if produced in advance. This creates high production volumes for certain years and low production volumes for the ones to follow. But of course every macro economical change has an effect in our company business decisions.

2 Research

AGCO Powers logistics department wanted to bring forward the current major challenges for supply chain management and what are the factors that drive these challenges. How the challenges could be managed in order to better achieve company targets. Goal was to find out where the development focus should be set so that it would best serve the business and at the same time choose and design the appropriate digitalization tools to better visualize, improve and optimize our supply chain management processes.

2.1 Research objectives

In order to better demonstrate the current state of supply chain management challenges in AGCO Power I wanted to reveal the current norms of our supply chain and in which pre-determined conditions we must form the appropriate supply chain development strategy.

As shown in the Figure 4 Supply chain lead time. AGCO Power has significantly lower lead times to its customers than from its suppliers. This means that in order to effectively serve our customers with the right products, we must efficiently forecast our customers demand or manage our inventories. Our experience showed that forecasting reliability is not high enough to completely remove inventory safety buffers and keeping some amount of inventory is mandatory to be able to keep high expectations for delivery performance. Although inventory buffers are a must, the most important question is, where and how much. Objective of this research was to demonstrate that with the current state of variety in our products, management of our supply chain processes create a high workload and without a carefully chosen strategy our processes will become more and more complex in the future. Complexity has a high cost but through intelligent planning we could be able to manage and decrease those costs.

2.2 Research approach and process

This thesis aims to underline the challenges and to investigate the matter and connection deeper. It aims to offer more information to base future developments of the company's supply chain processes and for this thesis we used exploratory research method to draw out the current problems in supply chain management.

Interviews were conducted to our supply chain management professionals, both managers and employees in order to discover the research focus and with secondary research methods such as literature and data gathering we studied the findings of our interviews in more detail.

We used company data from sales records, product structures as well as purchase records to prove the existence of our interview findings and compiled simulations with the data to test different hypothesis.

2.3 Qualitative and quantitative research

Qualitative research's aim is to test if the predictive generalization of a theory holds true. It can be constructed with an inquiry composed of variables, measured with numbers, and analyzed using statistical techniques. Qualitative research should be concerned to finding the answers that begin with why? How? In what way (Abawi 2008, 3-4)?

Quantitative research on the other hand collects numerical data in order to explain, predict and or control phenomena of interest. Quantitative research method leaves little room for variance since it is used to only proving or dismissing an already existing theory or hypothesis (Abawi 2008, 7-8).

These two research methods are often combined in a survey and often necessary to be able to make clear conclusions. I would characterize our survey as combination of quantitative and qualitative methods as well since the questions were limited to a certain phenomenon to aid further analysis, but left room for the interviewees to suggest different theories on our supply chain challenges. We also tested the results of our survey with data analyses and that can be characterized as purely quantitative research.

3 Premise & Staff Interview results

To shed light into our company's supply chain processes we conducted interviews with order management employees (Appendix 1.) and supply chain managers (Appendix 2.). Interviews focused on the challenges that our operational purchasing department professionals faced within their day to day work. Frame of reference in the interviews was the variability in demand and - supply and what effects does variability have in the workload and what are the consequences of that variability. Interview questions were divided into three categories which were variability, ability to react to variability and how are our professionals able to reach current targets. Most of the questions asked were multiple-choice questions to better delimit the answer deviation. We also asked one question in the first category where we allowed a more wider response because we wanted to know where the supply chain professionals would place the development focus in the supply chain, and especially where would they focus in order to reduce variability in demand or in supply.

3.1 Current challenges

Interviews clearly revealed that demand variation creates much more variability in our processes than supply variability. Most of the interviewed noted changes in demand to be clearly more challenging than changes in supply. Demand changes are of course a normal phenomenon in any manufacturing environment and forecasting is always a best guess of the future, thus changes should always be expected.

Although changing demand is a normal occurrence, what our supply chain professionals disclosed was that our demand has high variability in the short term period. Short term period being the four week time before start of production. Most of our efforts in securing the supply are placed in exception handling. Meaning that we need to negotiate supply changes with suppliers that are in conflict with supply agreements. This is also more commonly described as “firefighting” in our organizational culture. Which brings to us the first open question in the interviews, what kind of development would our professionals want to see in our mode of operations. In this question we discovered a bit of deviation in perspective between purchasing - and supply department functions. Purchasing function wants to create a longer frozen zone for our production plan and supply department which is responsible for delivering engines according to customer needs, would like to keep it as flexibility as possible in order to better serve our customers. Nonetheless all interviewed recognized the potential of balancing production, which could in turn result in balancing the demand and deliver the same effect as longer frozen zone of our production plan. In addition to these two factors we should better look into the demand we receive from our customers. With depended demand directly derived from customer master production schedule, without the effect of stocks in the middle we could reduce the amount of demand variability that occur from e.g. minimum stock quantity targets.

3.2 High variability in demand, high workload in order management

Although the demand variability clearly presented as the highest factor for creating challenges our professionals face today. Another important discovery was the high workload our processes require to react to these changes. Our order management is highly manual process due to restrictions in our current ERP system and in order to manage our supply schedules most of the orders and delivery forecasts need to be manually updated. Up to 50 percent of our current workload in the order management team is tied to order creation. This is a significant place of development since with today’s more intelligent information systems this process could be automated and the workload focus could be shifted to more productive efforts such as continuous improvement activities.

3.3 Management vision for future development

The questionnaire for supply chain managers focused on the development of current processes and how they see their employees working methods would change in the future. What would be the future vision for sales & operations planners and operational purchasers?

One of the most common development factor and what our management jointly brought up was visibility. Our most important management challenge lies in making our supply chain processes more visible. In order to better understand the current challenges and where resources should focus in AGCO Power, we must improve our visibility. Visibility of our demand – and supply variability. We should place more focus on negotiating service agreements with our customers and suppliers and put to place KPI’s to monitor how our performance, or our suppliers performance is able to follow these specified agreements. In addition to making service agreements for lead times, we could negotiate agreements for finished goods – or material stocks with our customers. In case customer expectations of delivery flexibility exceed the actual performance of our supply chain, we shouldn’t automatically agree to carry the risks involved but the terms should be negotiated together with the customer.

Secondly our management recognized the current state of waste in our processes, workload would be better utilized in continuous improvement activities such as monitoring overall performance of our supply chain and improving material flow. When the focus is on removing the waste of our operations, we also improve our service, quality and reduce costs. Not only should we create a strategy to manage our supply chain better but we should create standards on the basis of our strategy that encompasses our processes for the entire supply chain. When standards are in place for e.g. supplier lead time and order flexibility, we can identify exceptions and focus on making sure those exceptions can be managed in the future.

4 Management of variety in engine manufacturing logistics

With the proliferation of variants in products and materials, managing supply chain operations and material flow becomes more and more challenging. To be able dig deeper into the strategic challenges our supply chain management is facing we needed to study the complete product structure and build models we as a company are offering to our customers.

Product customization has always been seen as a competitive edge in customer satisfaction and sales, but rarely the complete cost structure and risks related to varietal increase are considered (Cooper & Griffiths 1994, 1).

James Cooper and John Griffiths (1994, 1) describe variety “as a number of possible states in a system.” Our supply chain will grow increasingly complex with every customized model or option we offer to our customers.

To effectively manage variety in our supply chain, we must equally increase the number of control mechanisms we have over our supply chain. The more complexity our supply chain withholds, the more complex must our techniques evolve in handling our supply chain effectively (Cooper & Griffiths 1994, 1).

As a product, engine consist of hundreds of components and since most of the components are sourced from a global network of suppliers, our inbound logistics systems need to be designed to manage the increasing number of complexity we are experiencing. Automotive industry has always been in the forerunner of our industry and now we in the agriculture equipment manufacturing business are also giving much emphasis on managing our operations effectively.

4.1 State of existing product variety in AGCO Power

First in order to grasp the state of component variation in our current product structures, we needed to understand what are the commonalities of different engine models and how the product is formed from components into a complete engine. In which stage of the engine assembly does our models vary from each other and is the component variation related to engine displacement, generation, customer or all of these factors. And which of these factors are the main reasons for component variation in key component groups. With more profound understanding on engine component variants and in which stage of the production they lie, we are able to suggest enhanced control mechanisms into our supply chain processes.

Currently AGCO Power Finland manufactoring plant has three different main production lines for serial production of engines and I have created a representation on what engine generations and sizes are produced in each different production lines. In addition to product categories in size and generation, I've counted the sum of different model options in each size category.

In addition to finding out how many different model options and engine displacement values each production line have. In this context it is also important to mention that commonalities are great within a certain cylinder class and though from a production point of view, it could be more sensible to observe commonalities and model variety through cylinder count rather than displacement (8.4, 7.4 and 6.6 displacement models all have a cylinder count of 6), from a supply chain management perspective we found diplacement class to be the main separator for certain key components. For that reason we wanted to study the component- and volume differences according to Figure 5.

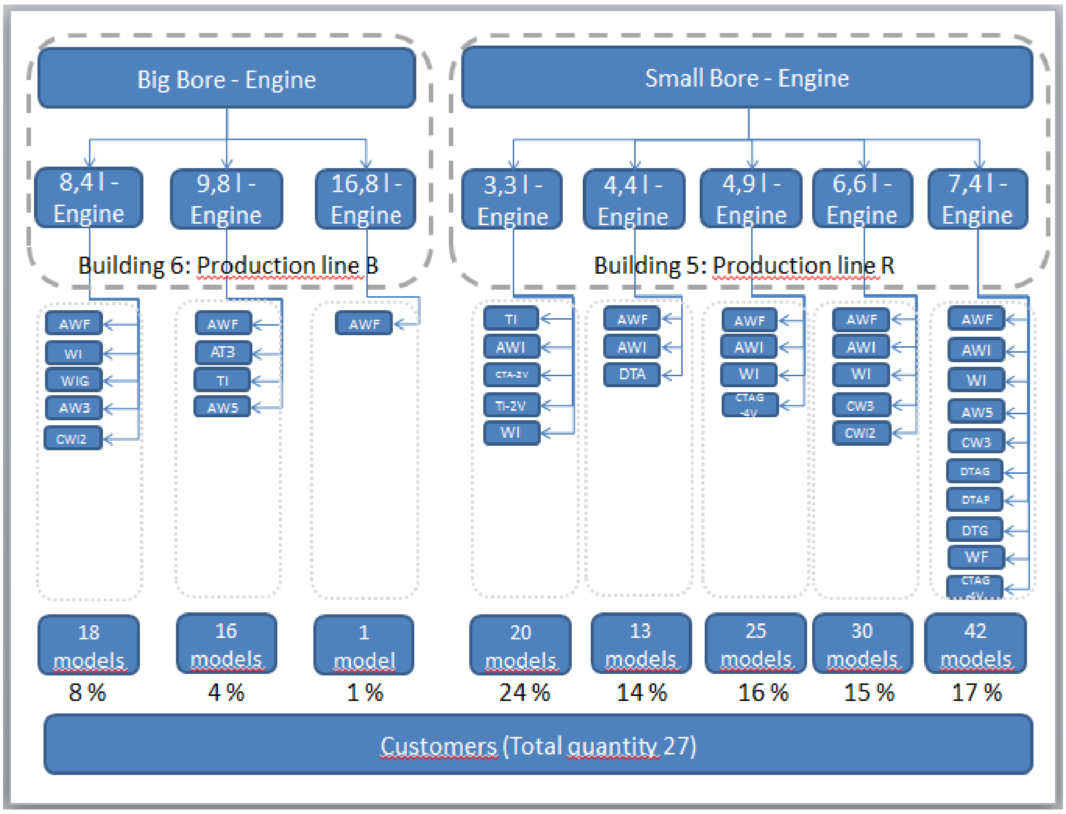

Figure 5: Engine model variants.

4.1.1 Current stages of variety in AGCO Power - Variation of components over product portfolio

AGCO Power has tens of thousands components that are needed in order to manufacture engines for our customers. Most of the components are rarely used and some are only used to re-manufacture old engine models or sold separately as spare parts, but the most attention and purchasing spend is paid into our serial production components. These are comprised of around 3500 different components and can be common (used in every engine model) or specific related to an engine displacement, generation or customer application.

To better comprehend the variation of materials under product portfolio, we needed to know how the materials were divided between the big bore engines and small bore engines (bore relates to piston diameter). And in order to do that we checked in which product line or lines a certain component is used.

Production line R used 47% of all the components in total and production line B used 30%. 77 percent of all components were separated into two categories which suggest that from a logistics point of view, the two production facilities were optimized in terms of variety management.

Our engine components (materials) vary according to what size of an engine they belong to. Engines have 8 different size categories of which the three largest belong big bore engine family and rest to small bore. Between the size categories we see variation in cylinder quantity and most of the component variation is limited to few key components such as crankshaft.

Most of our component variation can be rooted into the stage of product generation and customer application. Product generation determines the complexity of our engine since every new emission reduction development has increased the complexity and product quantity in our engines. In addition of course engines have been also developed to create more power with less consumption which is not just more environment friendly but also cost effective. Customer applications on the other hand have been developed to fit all our customer needs and for this reason many components have tens of different variations even though they are assembled into every engine no matter the generation.

4.1.2 Study case 1. Variation in key component categories.

To better understand the variation in our components I started with few key component groups and listed all the different component variants we currently manage in that particular group. In the figure 6 we can see all the different key component groups and total number of different components that we use actively in serial production.

Item group	Different item numbers
Exhaust manifold	47
Flywheel	35
Flywheel housing	32
Oilsump	31
Turbocharger	27
Water pump	21
Gearwheel housing	17
Crankshaft	15
Front cover	14
Intake manifold	13
Cylinder block	8
Generator	8
Damper	7
Kompressor	6
Starter	6
High pressure pump	4
Oil pump	4
Cooler	2

Figure 6: Component variation in key component groups.

To be able to dig deeper into what created this amount of component variation, I needed to know into what engine model these different components were used and to limit the amount of research I started with only one component group, oil sumps.

Component	% of total volume	Displacement	Cylinder qnt	Customer	Generation
Oilsump 1	11 %	4,4 l and 4,9	4	Customer A	AWF
Oilsump 2	15 %	6,6 l and 7,4	6	Customer B	AWF, CW3
Oilsump 3	5 %	4,4 l and 4,9	4	Customer B	AWF

Figure 7: Oil sump variety factors.

As stated before our engines have been developed to fit our customer requirements and that fact can also be seen in with our oil sumps. Oil sump is part of the tractors load bearing structure and for that reason the design has been tailor made to suit each customer tractor frame. Specific customer design factor is also creating variation in component groups such as flywheel and flywheel housing.

4.1.3 Engine emission regulations

As stated before, generation of the engine is one factor that drives diversity into our engine components. Most of the engines produced in Linnavuori factory serve our customers in Europe or North America and the emission regulation stage in these continents are the most demanding, Tier 4 final in North America and Stage 4 in Europe. Emission level requirement in these two is the same.

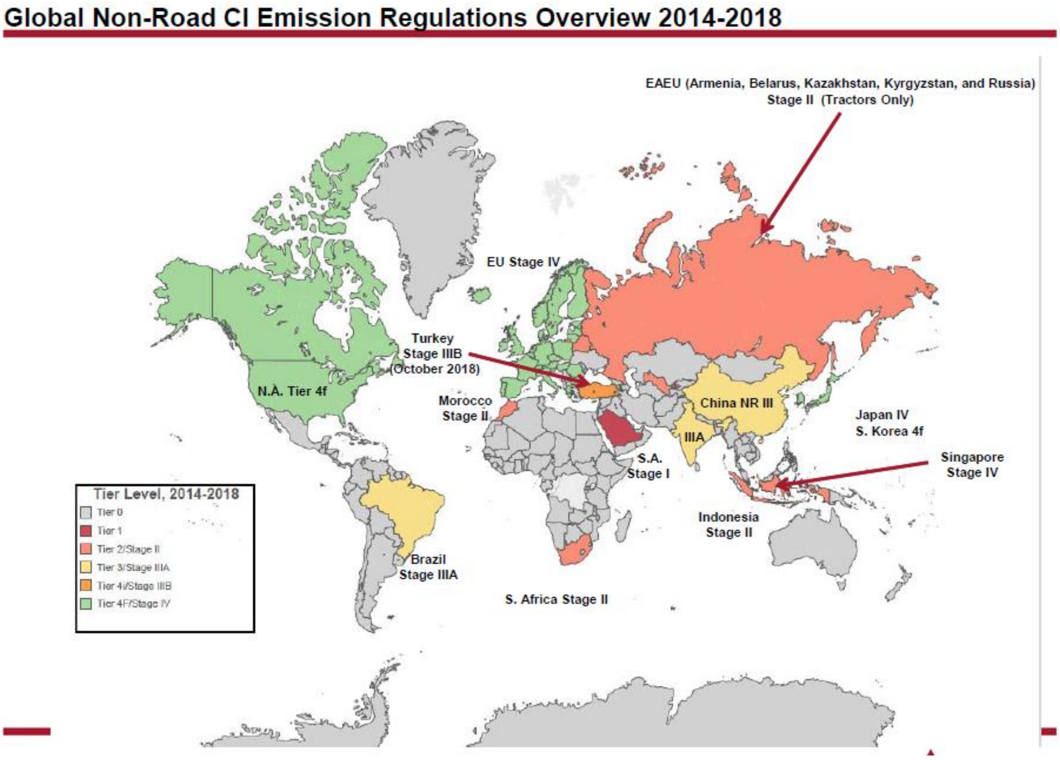

Figure 8: Emission Regulations overview 2014 – 2018.

Due to constantly tightening emission regulations, new engine designs need to be develop with a staggered schedule. Complexity of the engine increases with each generation and so does the component quantity. Although most of engines are at the moment generation 4 engines, some small customers still purchase generation 3 engines to parts of the world where stage 3 engines can be used. Volumes of these old generation engines are very low but handling the purchasing and logistics activities creates just us much effort as with the parts related to new engine generation with higher volumes.

4.1.4 Future analysis - is variety increasing or decreasing

As we discovered in the previous chapters component variation is dependent on many factors such as engine size, customer application and engine generation. New product introduction projects are usually related to module development projects such as designing a completely new engine generation or completely new engine family. They can be projects related to product development requests from customer or current product requests that are usually initiated to improve quality or engine performance. From the ladder project types new components replace the old ones almost without exception and the variation of components doesn't increase over time, but from an engine generation point of view, our component variation is definitely increasing.

Old engine generations are still assembled in our serial production lines even though the volumes are extremely low. To this aspect we should direct more focus and determine if the old low volume models should be compiled and managed in our factory or in our serial production line. As we are moving on to engine generation 5 our South American factory is also moving to generation 3 in the engine design and low volume generation 3 models we still build in Linnavuori factory might be more efficient to be built in our South American factory.

4.2 What are consequences of variety in SCM

Since we established that our products and materials exhibit a large number of variation, we needed to know the consequences that variation has on our processes and how variation can be managed.

James Cooper and John Griffiths (1994, 4) suggest that logistics consist of a number of interlinked systems or processes that each display a changing level of variety. That variety in each system or process determines how effective we are in managing these systems. In order to run our logistical processes and systems efficiently we must decrease the amount of variation they encapsulate.

High level of variety have a high effect on logistics management in multiple aspects and issues related to variety and complexity are strongly linked. Whenever variety is high, our supply chain represents complex linkages. Complex linkages result in higher throughput times, costs and exceptions in our logistics operations (Cooper & Griffiths 1994, 1).

The research explains that associated with complex logistics linkages we have three rules that actuate management over complexity (Cooper & Griffiths 1994, 1).

Rule 1. Increased variety add to supply chain complexity.

James Cooper and John Griffiths (1994, 4) illustrate that within the automotive industry both indirect and direct cost are increased with addition on variety. In figure 11 (chapter 4.2.4 Logistics processes) they have categorized differences of logistics operations between two companies that work with different variety levels. To better understand in which variety level AGCO Power operates. I have evaluated how these operations could be described in our organization. By evaluating the complexity of our logistics processes we discovered that AGCO Power operates under multiple variety (similarly as case B company, evaluated in figure 11). Although our variety isn't as high as in automotive industry, the processes are as complex.

Rule 2. Variety should only be increased only when it contributes to added value.

Comprehension of rule number two is not difficult, but putting it into practice is extremely difficult. Many companies in the industry have experience in costing purchases and have introduced these techniques to procurement. Supply cost analysis has evolved purchasing to evaluate component costs through transparent cost structures of manufacturing and enabling value analyses that e.g. lean production – philosophy relays on. With transparent product costs we are able to suggest improvements in processes of particular components, but it is much more difficult to define the point where systems need to be redesigned in order to cope with variety (Cooper & Griffiths 1994, 4-6).

With the introduction of an extra flywheel housing specification we will suffer from a loss of economics of scale in purchasing, but also the impact on indirect costs through logistics complexity might be substantial. System control is almost impossible to forecast. How are we able to control our systems with added complexity? When variety increases and we have to micro forecast each different variant, especially in a difficult global supply chain environment with long transport and lead times, forecasting process can be extremely unstable. Change is constant and most of the costs are derived from trying to cope with the state of change and exceptions. It is seen as a common issue, almost a norm that every time we input a new forecast to our ERP, changes create delivery problems that cannot be managed.

In case costs related to varietal increase are considered, we rarely consider the indirect costs such as administrative costs. It is very important to understand that complexity adds to administrative costs even if sales remain the same. As the article suggest costs from low volume products are usually allocated to high volume products, since the difficulty in measuring all costs related to a certain product (Cooper & Griffiths 1994, 6).

In AGCO Power almost 60% percent of our sales are generated from only 10% of our products and more than 50% of our products generate only 5% from our sales. We could then presume that 50% of our administrative costs generate only 5% in sales for our company.

Rule 3. System redesign can create added value through reducing cost impacts of variety.

As we have more comprehensive understanding on how variety impacts supply chain, we can analyze how variety should be managed. Most important factor in mitigating the effects of variety is lead time. Inventory carrying costs are usually related to lead time. With long lead times uncertainty increases and as a result inventories are increased (Cooper & Griffiths 1994, 7).

When operating in a high variety environment lead times play an important role in combatting against the forecast inaccuracy. Sourcing- and manufacturing lead time should be adjusted to equal the lead times of offerings but in most of the companies this is not the case. We must hold some inventory to cope with the fact that sourcing and manufacturing together entail much higher lead times than our customer except when placing an order.

James Cooper and John Griffiths (1994, 7) imply that using sophisticated information exchange tools we can shorten the lead time of information flow and thus reduce the uncertainty of forecasting, but when demand variation is high, forecasted demand should be decoupled rather than transmitted without careful overview. With reconfiguring logistics systems as lean as possible there’s a possibility to reduce inventories even though product order lead times remain short.

4.2.1 Material requirements planning and managing variability

Material requirements planning is a system used for production planning, scheduling and inventory control. MRP aids professionals to manage daily manufacturing processes and make sure materials are ordered and delivered on-time, planning manufacturing activities and maintaining service levels at the lowest possible inventory.

Ptak and Smith (2011, 11) explain that manufacturing should be perceived as a process and by understanding how it should work is essential to company’s success. Essence of manufacturing and supply chain management is the flow of goods from suppliers to customers. Benefits in a successful manufacturing process are gained through a speedy flow of materials and information. Within that process it is crucial that all parties involved receive accurate and timely information about what has been made, when it has been made and what should happen next. As material and information flows speed up difficulties in manufacturing controlling will decrease and planning becomes more effective.

In today’s business environment manufacturers and supply chain professionals are faced with challenges never before presented and yet our supply chain management techniques remain mostly same as decades ago. In modern supply chain management we must apply our strategy and techniques to manage such challenges as (Ptak & Smith 2011, 12):

1. Global sourcing and demand
2. Increased outsourcing
3. Shortened product life cycles
4. Shortened customer tolerance times
5. More product complexity and/or customization
6. Demands for leaner inventories
7. Increasing forecast error
8. Material shortages
9. More product variety

10. Long lead-time parts/components
11. A hypersensitive global economic community
12. Dramatic cutbacks in personnel and other resources across the supply chain

Most even if not all of these factors are present in today's manufacturing business and contribute to volatility of our core manufacturing processes (Ptak & Smith 2011, 12).

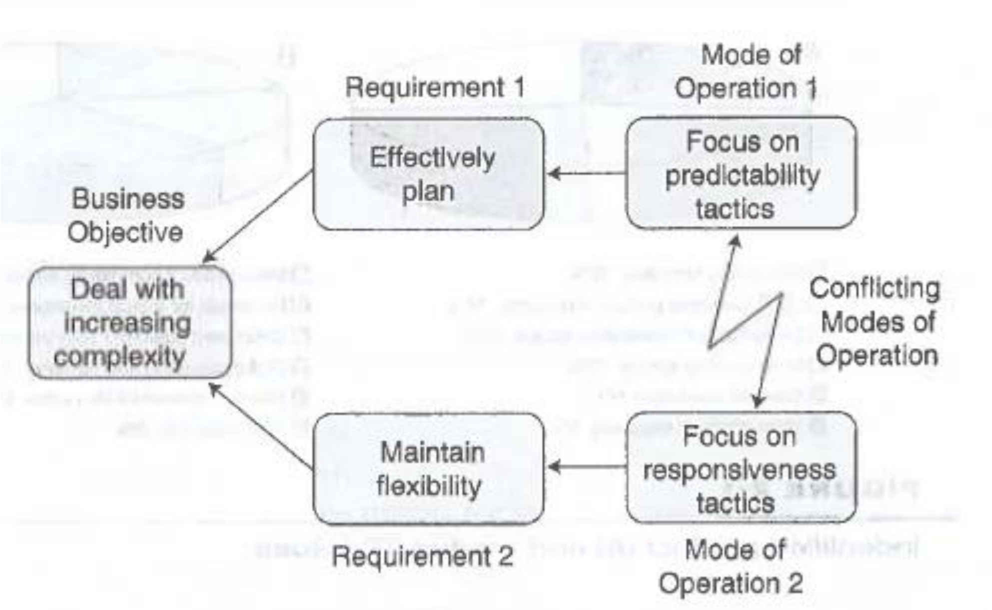

Figure 9: Current operational planning conflict (Ptak & Smith 2011, 14).

As seen in the figure 9 Ptak and Smith (2011, 14) have identified two different operations modes that are employed to manage this volatility and as the figure represents these two different operation modes are in conflict with each other. First operation mode describes how companies that have adopted this approach must accurately predict the future. Customer demands must be planned in advance before actual demand arises and the demand must be accurate. In order to achieve leaner inventories with increased delivery accuracy to customers in an environment where customers have continuously shortened tolerance times and continuously increased lead times for components, planning the future correctly is vital for success. Companies have to develop very sophisticated processes for sales and operation planning in order to minimize variability in the planning horizon. Companies could attempt to create advanced forecasting algorithms in order to forecast better or improve customer relationships to gain further insight into their demands (Ptak & Smith 2011, 14).

Second mode of operation focuses on increasing flexibility in the supply chain. When operating with high complexity, increasing flexibility could counter effect the target to achieve leaner inventories. Flexibility creates advanced commitment to capital, inventory and capacity and this in fact makes the company less flexible to change. Flexibility also predisposes manufacturing plans to variability, which usually drives organizations to get rid of sophisticated operation systems rather than developing them further. LEAN techniques are usually seen as a way to fix the problems experienced with high demand variability, but when working with pull systems such as Kanban, inventories tend to grow significantly (Ptak & Smith 2011, 15).

Both of these techniques practiced individually are in most manufacturing environments inadequate and the improvements we do for planning, hurt our ability to be flexible. That is why companies should seek for a solution that allows them to be flexible while maintaining an effective planning horizon (Ptak & Smith 2011, 15).

4.2.1.1 Managing variability

To be able to design our production and supply chain for effective and flexible planning. We should address these key questions. How can we eliminate shortages and production schedule changes due to material unavailability? How do we keep production and supply chain lead time as short as possible, without carrying extra inventory? How can we keep working capital synchronized with demand? (Ptak & Smith 2011, 15).

In order to answer these questions we must understand how much complexity our supply chain contains and we must find a way to protect ourselves against this volatility. Variation is on the rise and has been for many years due to customization of product offerings. To be successful in managing variability organizations should understand that with variation comes variability and with efforts to lean out inventories we expose ourselves to extreme variability, which may paralyze our operations completely. It is possible to manage variability, but removing it is impossible without re-designing company's product offerings or bill of materials. In case we have to increase variation, we should protect our supply chains from variability with inventory, capacity or time. And in order to plan against variability, how can we identify sources of variability (Ptak & Smith 2011, 16)?

4.2.1.2 Demand variability

Demand variability is defined as fluctuations and deviations in customer plans. Forecast inaccuracy is sometimes considered as fluctuating demand variability but it is not the same thing. Inaccurate forecasting is a result of demand variability, since forecasting becomes extremely difficult due to fluctuating demand patterns in customer needs (Ptak & Smith 2011, 17).

Working under high demand variability is very time consuming for the supply chain operations. With every change in demand we must align our production and purchasing activities to match the new demand scenario (Ptak & Smith 2011, 17).

4.2.1.3 Supply variability

Supply variability can be identified by measuring deviations from promised shipment – or arrival dates in the purchase orders. Reliability of our supply network defines how high is our supply variability. It is important to understand that even though our supply service levels to production are high, our supply reliability might still be significantly lower (Ptak & Smith 2011, 17).

4.2.1.4 Operational variability

Or common-cause variation. System exhibits variation even though it is in a steady state. This mode of variability is also commonly called as murphy’s law. Process generates variability within the statistically calculated limits, even in companies practicing lean approaches, because perfection in every process is impossible to achieve (Ptak & Smith 2011, 17).

4.2.1.5 Self-imposed variability

Self-imposed variability is created by persons responsible of carrying out the process. Processes generate “noise“ or a different outcome even though the process is started with the same premise every time. That is why it is important to identify when processes are necessary to be launched. In case we know there’s no change in customer demand, S&OP – process should generate information that allows certain processes to stand still without execution. Without that information, even though customer demands have remained the same, purchasing functions might change their plans, which in turn creates demand variability in the supply network (Ptak & Smith 2011, 17-18).

4.2.2 Bullwhip effect

When working with MRP and purchasing, MRP nervousness and how to manage it, is the essence of material planners daily routines. Bullwhip effect is the first thing a new planner learns when working with MRP in a complex supply chain environment. Even a small change in the upper stream of the supply chain can cause a major change downstream. It is common that when these changes occur in the near future of demand for a manufactured product, component deliveries can be required immediately or demand might even be generated in the past. When we have minimum order quantities, safety stocks and unrealistic due dates that amplify the bullwhip effect, it might very be difficult to decide what to actually request from the supplier (Ptak & Smith 2011, 18-19).

Bullwhip effect is visible when measuring variability throughout the supply chain. Measured total system variation is significantly higher than variation for a single component in any node in the bill of materials. Typically bullwhip effect is represented by a graph that illustrates a straight flow from suppliers to manufacturers and to customer. Bullwhip is amplified from start to finish within the flow. This is of course true but it oversimplifies the actual situation material planners are faced with. Supply networks aren’t straight flows from supplier to production. Single product might have tens or hundreds of suppliers and each supplier has second tier suppliers. The more complex our supply chain is the more complicated bullwhip effect is to manage (Ptak & Smith 2011, 18-19).

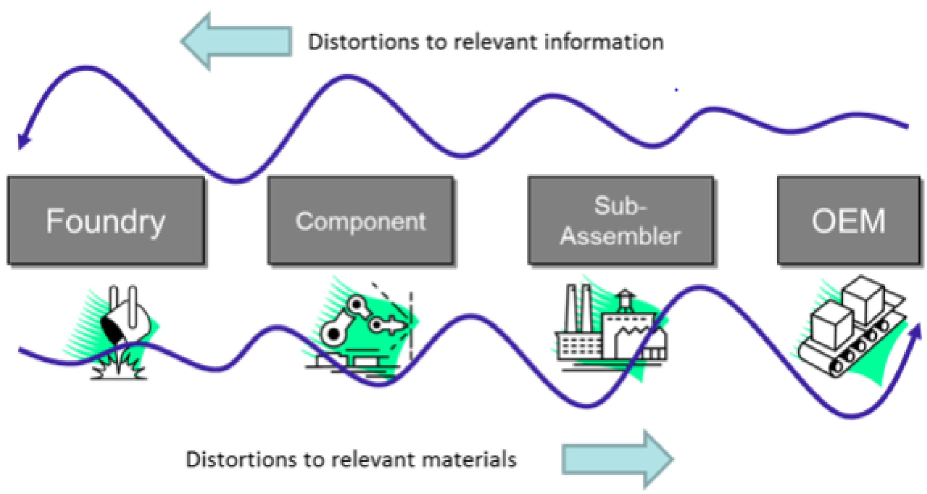

Figure 10: Bullwhip effect (Prime advantage blog. 2016).

4.2.3 Forecasting

Supply chain management comprises of coordinating information flows between various members of a supply chain. These members include manufactures, distributors, suppliers and even third party operators. These information flows effect directly into our production scheduling, inventory control and supply schedules for our suppliers. Hau L. Lee, V.Padmanabhan and Seungjin Whang (2004, 1) study the distortion of demand information as it passes along the members of the supply chain.

Paper studied the real demand data of retailers sales of a product compared to retailers orders to the manufacturer. In this paper they prove that the actual sales have a smaller variance than the purchase orders. This phenomenon is called bullwhip effect or whiplash effect. Demand information distortion and bullwhip effect will affect manufactures that only observe its immediate order data or customer forecast. Amplified demand patterns will emerge and it has serious cost implications. These cost implications could include excess raw material stocks, excess manufacturing capacity, inefficient utilization and overtime of the workforce, additional warehousing and transport costs due to distortions in relevant information about the actual relevant demand. (Lee, Padmanabhan & Whang 2004, 1).

When demand information is derived purely on customer orders or forecast it will be subject of amplified demand patterns that shift in time as we have noticed in our company. Forecasting inaccuracy or demand variability is assumed to be especially high in our case since forecasting is targeted to multiple products that are all under the same capacity restraints. Capacity allocation cannot allow major shifts in demand and customer demand need to be balanced according capacity restrictions. Due to short fixed production plan in our company capacity planning and demand fluctuations as a result create changes in short term planning for order management team.

4.2.4 Logistics operations

Reducing complexity in our logistics systems is an effective method in reducing the cost effects of increased variety. Common rule of increased variety as James Cooper and John Griffiths suggest is that when variety tends to add to the complexity of logistics operations, it in turn increases both direct and indirect costs (Cooper & Griffiths 1994, 6).

How can we identify exactly that increased variety will contribute to increased direct and direct costs? James Cooper and John Griffiths (1994, 6) have formed table which presents an example of logistics activities of two different companies with different degree of variety. Through the activities we can observe the consequences arising from high variety and the advantages of low variety in the logistics systems. High variety system in this example demonstrates the logistics system of an automotive company that works under a high degree of variation.

Case A (company 1) has little or no variety contained in their logistics systems and Case B (company 2) has plenty or multiple variety contained in their logistics systems. In addition to Case A and B I have added Case C (Agco Power) in the table and described the logistics activities of our organization in comparison to case A and B. Observing the logistics activities of our company we can assume the degree of variety and complexity encompassed in our system (Cooper & Griffiths 1994, 6).

What we can detect from the figure 11 is that most if not all the logistics activities in our company are similar than with the high variety company example B. Our forecast is disaggregated by model option which allows the derivation of detailed part specific forecasts for our suppliers. Our build schedule requires balanced work content in order to be as efficient as possible. Capacity planning is dependent on model mix since model configuration determines the work content of a specific model and the work content complexity differs greatly between model configurations. Part ordering requires MRP or Kanban systems, but the most variety revealing logistics activity in our company is part selection from inventory. Parts are picked and delivered to production line from supermarkets according to specific engine model in order to save space in the production line. This activity is necessary to avoid poor utilization of production workforce.

Activity	CASE A (No variety)	CASE B (Multiple variety)	CASE C (AGCO POWER)
FORECASTING	VOLUME ONLY	FORECASTS DISAGGREGATED BY MODEL DESTINATION, OPTION, COLOR, ETC. TO ALLOW DERIVATION OF DETAILED PART / SUPPLIER FORECAST	FORECASTS DISAGGREGATED BY MODEL, OPTION, POWER TO ALLOW DERIVATION OF DETAILED PART FORECAST
BUILD SCHEDULE	VOLUME ONLY SIMPLE FACILITY	REQUIRES BALANCED WORK CONTENT OR HIGHLY FLEXIBLE FACILITY	HIGH FLEXIBILITY WITH BALANCED WORK CONTENT
CAPACITY PLANNING	VOLUME ONLY	DEPENDED IN MODEL MIX FORECAST AND PLANNED SUPPLIER SPLIT	DEPENDEND ON MODEL MIX
PARTS ORDERING	VOLUME SCHEDULE TO EACH SUPPLIER	REQUIRES DEVELOPMENT AND OPERATION OF MRP OR KANBAN SYSTEM	REQUIRES DEVELOPMENT AND OPERATION OF MRP, HIGHLY FLUCTUATING DEMAND
STORAGE	SIMPLE METHODS, LOW SPACE	COMPLEX SYSTEMS FOR PART STORAGE AND RETRIEVAL OR SIMPLE SYSTEM WITH POOR UTILIZATION	COMPLEX SYSTEMS REQUIRED, POOR UTILIZATION AND LOW INVENTORY ROTATION
SUPPLIER MANAGEMENT	LOW OVERHEAD	INCREASED OVERHEAD	HIGH OVERHEAD, CONSTANT "FIREFIGHTING"
DELIVERY METHOD	LOW NO. OF DELIVERIES ALL HIGHLY UTILIZED AND PREDICTABLE	HIGH NO. OF DELIVERIES FROM POORLY UTILIZED AND UNPREDICTABLE RECEIVING WORKLOAD	HIGH NO. OF DELIVERIES FROM POORLY UTILIZED AND UNPREDICTABLE RECEIVING WORKLOAD
PART SELECTION FROM INVENTORY OR ON ASSEMBLY LINE	SIMPLE	COMPLEX SYSTEMS REQUIRED TO INFORM OPERATOR OF REQUIREMENT UNIQUE PART ID REQUIRED	COMPLEX SYSTEMS REQUIRED TO PART SELECTION, UNIQUE PART ID REQUIRED.

Figure 11: Logistics consequences arising from low and high variety systems (Cooper & Griffiths 1994, 6).

4.2.5 Sourcing of components

Component sourcing can be categorized in AGCO Power as global sourcing. AGCO Power has four different manufacturing units based in Europe, Asia and South America for which the purchasing activities are coordinated jointly.

As Robert M. Monczka and Robert J. Trent (1991, 3-4) explain in the article Global sourcing: A development approach. In order for an organization to graduate from international sourcing to global sourcing, certain characteristics of international procurement need to be met. Article points out that, organizations gradually reach these characteristics as their international procurement strategies evolve. The last step of procurement internationalization entails that purchasing organization recognizes the greater benefits of coordinating and integrating purchasing activities and efforts on a global scale. These phase four given characteristics of procurement identify a true global sourcing efforts opposed to international purchasing characteristics. Few given characteristics of phase four sourcing are described by

Monczka and Trent (1991, 4) as realization of global sourcing benefits, requirements of information are identified as critical, executive level manager is designated to coordinate global efforts and integration and coordination of global sourcing requirements. Monczka and Trent (1991, 5) also point out that since global sourcing represents the most sophisticated sourcing strategy, the requirements for managing the sourcing process are great. In order to successfully carry out the strategy, organizations should possess worldwide information systems, advanced personnel competencies, extensive coordinating capabilities and effective organizational structure.

David L. Levy (1995, 1) has studied international sourcing and supply chain stability for the journal of international business studies and suggests that international supply chain can be conceptualized as a complex and dynamic system where disruptions generate higher costs than in a more simplistic domestic supply chain, due to higher lead times. Study found that demand-related disruptions created higher costs in shipping, inventories and lower demand fulfillment. In time the production related disruptions declined in the reviewed companies, but demand-related disruptions remained.

As our sourcing strategy can be recognized as global sourcing, we can also identify the same disruptions in our supply chain as Levy presents. Since international sourcing has been practiced in AGCO Power for an extended period, our disruptions for production have been eliminated through time, but demand-related disruptions are very much present as the interviews for our supply chain professionals indicated. High inventories have formed to combat against disruptions in the supply and as our supply chain complexity increases we will experience more substantial disruptions. Our expediting transport costs are annually very high as is our inventory values. And as we have discovered, operational costs increase through global sourcing and our sourcing strategy should consider all related costs in order to make sourcing decisions that take into account our entire value chain. As later described in chapter 7.4.1 Total cost of ownership.

4.3 Single sourcing vs. multiple sourcing

Single sourcing as a part family level reduces complexity significantly in logistics systems and processes. Administrative effort in managing a single supplier is much lower than number of suppliers in the same part family. On the other hand in multi-sourcing strategy suppliers compete against each other from the same volume and this setup usually drives the unit costs down. Multi sourcing can also be seen as a strategy to reduce risk of supply. In a situation where supply has interference from one supplier, it can be possible to source all needed components from the second supplier. In addition to the above mentioned factors, capacity planning should also be included in the sourcing decisions as usually demand fluctuates with components in the same part family. James Cooper and John Griffiths (1994, 4) argue that when sourcing an entire part family from a single supplier, when demand decreases from a certain component, it increases with another and the overall capacity will remain the same. As the capacity requirement remains the same it will reduce the risk of supply shortages and reduce complexity in the supply chain.

One important aspect of improving logistics processes is delivery condition. As explained earlier complexity occurs in our supply chain and choosing appropriate delivery condition doesn’t remove it, but when optimizing the costs related to complexity, delivery condition plays an important role. Operating- and inventory carrying costs can be significantly reduced by implementing a more complex delivery methods from our suppliers. Just in sequence delivery is an effective method on reducing handling in the manufacturing and it drives inventory down, since components are only delivered when production schedule has been locked or “fixed”. This usually happens at the very late stage on production scheduling. Just in time delivery method also has a very drastic effect on inventory, but it isn’t as cost effective as just in sequence. Both of these delivery methods rely on very low lead time of supply and implementing these methods are usually only possible with local close by suppliers. Problem in using a more sophisticated delivery methods is that in most manufacturing companies supply networks are coming more global and lead times for delivery will often become extended (Cooper & Griffiths 1994, 4).

4.4 How can we exercise control over variety?

As competition in most business sectors increase it is imperative to find new ways to improve efficiency and satisfy increasing customer demands. Adding variety to product ranges is often necessary in order to satisfy customer demand, but in order to improve our efficiency we must understand the costs related to varietal increase and how it effects our delivery performance for our customers. In AGCO Power customer demand is not the only source for high variety, government regularity legislation in engine emissions is also an important factor for increasing variety in our business segment.

As automotive manufacturers have realized the critical success factors in managing variety can be summarized with four aspects (Cooper & Griffiths 1994, 11).

Variety should be assessed through costs and benefits. Although it is not an easy task to evaluate how increased variety will effect added value or what are all the costs related to variety, it is important managerial knowledge that there are many different costs related to increasing variety and it shouldn't be seen only as a benefit. Costing methods and cost analysis should be developed in order to sensible attribute costs. Traditional costing methods might lead to poor business decisions and costs related to varietal increase might outweigh benefits we gain (Cooper & Griffiths 1994, 11).

Timely and accurate information is the key in managing variety. We must improve our information systems in order to reduce information lead times. Manufacturing environment where variety is high it is important to react to changing conditions fast and as important as timely information is that the information is correct. In case delivered information is not reliable and information systems feed that information faster, it might result in even poorer performance than with more extended information lead time (Cooper & Griffiths 1994, 11).

New aspects to buyer supplier relationships. In order to reduce the amount of complexity in our logistics systems, sourcing decisions need to be evaluated with logistics in mind. Successful reduction in unwanted impacts of variety, we might build supplier component portfolios through single sourcing strategies and in order for that strategy to be successful we need to pay attention in buyer – supplier relationships and maintain more co-operative approaches in our relationships (Cooper & Griffiths 1994, 11).

Logistics systems re-design is vital in improving efficiency and managing variety. There's no single right answer or method in re-designing logistics systems. They need to be designed to fit the company's supply chain standards and conditions (Cooper & Griffiths 1994, 11).

4.4.1 Lead time reduction

Hopp, Spearman and Woodruff (1990, 1) have conducted a detailed study of six manufacturing facilities to explore causes of excessive lead times and to suggest strategies for reducing it. Study was conducted almost 30 years ago, but most of strategies are still valid to make todays companies operations more efficient and profitable. As noted in the study, process time of a certain product added up to hours whereas the average flow time was as high as 4 weeks. Hopp, Spearman and Woodruff (1990, 1) emphasize the meaning of lead time reduction in order to advance the competitive edge of company's manufacturing. It is mentioned that lead time reduction is a strategy that usually production and sales departments can agree on and from the perspective of sales:

- lead time reduction can enable ability to offer faster delivery times to customers,
- lessen the impact of cancelled orders,
- decrease the importance of creating accurate forecast for the future.

From the production point of view these advantages could be:

- quality management as the time from detecting the defect is shortened,
- reducing in-process inventories,
- enabling shorter frozen zones and thereby reducing the need for distant forecasts
- easier management of the production facility as there will be fewer jobs to keep track of at the same time.

(Hopp, Spearman & Woodruff 1990, 1).

The benefits of flow time reduction cannot be argued and many companies in AGCO Powers supply network still have high flow times in their production today. In order to achieve competitiveness, flow time should be carefully evaluated and shortened if possible.

In addition to flow time reduction, todays companies should study the supply chain lead time and try to reduce the overall lead time of the supply chain. Flow time reduction solely doesn't remove the need for accurate forecast for the future, since most manufactures production capability relies on components or raw materials supplied from other supply chain participants upward the chain. Overall lead times of AGCO Powers supply chain might expand up to 18 weeks as the suppliers lead time for raw material might be as high as 3 months and in case detailed attention is not paid to forecasting, our supply chain disruptions could be drastic.

Production scheduling is also a notable factor in high customer lead times (order to delivery) since production usually requires a fixed production plan in order to plan capacity use as high as possible and when there's no flexibility embedded into production capacity, requirements for fixed period time tend to rise.

4.4.2 Decoupling and Strategic buffers

In order to manage variability and bullwhip effect to pass on we must decouple dependencies within the supply chain. Decoupling enables variation to be dampened or stopped within the nodes of the system. Ptak and Smith (2011, 20) illustrate variation decoupling through break walls in marinas, break walls are created to break the wave before it hits the marina and boats. Size of the break wall is a direct derivate of the expected size of the generated wave in the sea. To effectively compete in today's business it is important to decouple variation where its effect to our system performance is the most damaging. These decoupling points should be designed in critical dependencies rather than all dependencies. This can be achieved through strategic inventory positioning. Rather than carrying inventory with all components or products, we must choose carefully components and products for which it is necessary to hold inventory, in order to dampen variation. Inventory is the most common way to decouple dependencies but it isn't the only way to do it. There are three different forms of buffering and they are time, capacity and stock.

In this study we will focus on strategic inventory positioning as capacity - and time buffers aren't included in the frame of reference.

4.4.2.1 Strategic inventory positioning

Rather than how much of inventory we should carry in any point in time, we should consider where our inventory and decoupling point will be placed. Ptak and Smith (2011, 62) have described six factors used to determine the initial positioning strategy. These factors are:

1. Customer tolerance time: *Lead time customers are willing wait for a delivery.*
2. Market potential lead time: *Lead time that allows new business opportunities.*
3. Variable rate of demand: *Potential swings or spikes in demand.*
4. Inventory leverage and flexibility: *Number of options where to use the inventory.*
5. The protection of key operational areas: *Protect critical areas from disruptions.*

With DDMRP (demand driven material requirements planning) these factors are applied and tested systematically to the bill of materials, routing structure, manufacturing facilities and supply chain in order to determine the best possible position for inventory (Ptak & Smith 2011, 62).

Ptak and Smith (2011, 63) suggests the way to realize how to best leverage inventory and set inventory levels properly is through actively synchronized replenishment lead time. ASR lead time defines the qualified cumulative lead time in the longest unprotected/buffered sequence in the bill of materials. ASR lead time differs from manufacturing lead time (MLT) and cumulative lead time (CLT) by realizing that not all components are stocked and available at all points of the supply chain as MLT assumes. On the other CLT defines the longest route in the BOM structure with cumulative lead times assuming that none of the items are available to be shipped from the supplier at the time they are required. ASR lead time is a more realistic approach to cumulative lead time estimation as in practice we know that the state of the supply chain material availability is somewhere in between these two extremes and thus should be planned as such.

When we analyzed our latest forecast for our products we calculated the amount of active (build forecast for the next 12 months is at least 1 engine) products to be 169. ASR lead time requires also a deeper look into our product structure (BOM) so for that we chose the product which has the highest volume of all our products. After the BOM explosion we counted the amount of components to be 489, created under 31 different layers for this specific model. Some models can be constructed of more than 800 different components. Due to complex product structure and high variety of products we found the exercise of ASR lead time determination to be too laborious. Even with one parent item the exercise seemed difficult but with the dependencies of hundreds of components in more than 160 different BOM structures we decided to look for a more simplistic answer on where to place strategic inventories.

Strategic inventory positioning provides many benefits and by carefully planning the location we might gain such benefits as reduced shortages, improved support for schedules, improved service levels, reduced expediting costs, reduced lead times and reduced system inventories (Ptak & Smith 2011, 392).

A more simplistic way to determine the inventory positioning was to examine the total inventory investment and reduction of demand fluctuation. We decided to build simulations on different inventory positioning models and observed them through the total investment for inventory target. First in order to calculate the different scenarios for our inventory investment, we needed to set two important strategic rules for our inventory target:

- How long is our fixed production plan?
- What is expectation for supply accuracy or service level?

Fixed production plan period ultimately determines how many different materials we can call-off from the supplier just in time and eliminate the need for inventory holding in our warehouse. In this case we decided that some flexibility is needed for our production plan changes, so in order for that to be possible some inventory is always needed for all components. Other important decision was the expected delivery performance level, which will contribute to the amount of safety stock required for a certain product or component. We used a specific inventory calculation technique created for AGCO Power to illustrate how much our total inventory investment would change with a few chosen strategies. Our model for inventory target determination is not as sophisticated replenishment model as DDMRP but it is easier to calculate and works for the purpose of simulating the overall inventory costs.

We used the company forecast data from week 35, 2016 since some of the strategic decisions had already been implemented at the beginning 2017 before this simulation had been conducted. Using data from last year enabled us to evaluate demand fluctuations when inventory positioning was placed at component inventory and no decoupling efforts had been made to customer demand.

We created target inventories for one product depending on how frequent deliveries the customer expected. Our forecasting is summarized by weekly quantities and also many of our customers request weekly or monthly call-offs in order to optimize delivery costs, but for some major customers we deliver engines daily. Product we chose to simulate inventory investment costs had one of the highest volumes and the customer was located at close proximity to our manufacturing location. After that we calculated the target stock values for daily and weekly call-off frequencies. Calculation was conducted from the following information:

- Average daily stock quantity (2016)
- Average usage
- Demand variation

Average usage was derived from forecast data and demand variation from ERP consumption records. We found that with daily call-offs for this product our inventory investment would increase by 176% (product inventory) and with weekly call-offs it would increase by 1282%. For this particular customer and product call-off quantity is closer to daily than weekly due to high volume.

Product 1	Quantity	Product	Product 1	Quantity	Product
Annual demand (forecast)	1711	engines	Annual demand (forecast)	1711	engines
Average daily stock quantity (current)	11	engines	Average daily stock quantity (current)	11	engines
Average weekly usage (forecast)	36	engines	Average daily usage ADU (forecast)	7,2	engines
Average weekly usage (history)	41	engines	Average daily usage ADU (history)	8,2	engines
Weekly demand variation (forecast)	6	engines	Daily demand variation (forecast)	1,20	engines
Weekly demand variation (history)	9	engines	Daily demand variation (history)	1,8	engines
1 day lead time	Quantity	Product	1 day lead time	Quantity	Product
Safety stock	33	engines	Safety stock	7	engines
Minimum stock quantity	78	engines	Minimum stock quantity	16	engines
Maximum stock quantity	231	engines	Maximum stock quantity	46	engines
Average stock quantity	14	engines	Average stock quantity	14	engines
Average stock value increase	1282 %		Average stock value increase	176 %	

Table 1: Product inventory calculation.

Now that we had a base for our inventory investment simulation we calculated the investment value difference for the every active product in our company as the complete investment value target for our component inventory. Our simulation model assumed that if the decoupling point is placed to product inventory (Finished goods) the demand variation can be expected to be dampened into 0% for the component demand because with finished good inventory we are able to remove fluctuating demand to production. This is of course not the case since some variation can and should always be expected due to uncertainties in production capabilities and component availability, but for the sake of simplifying the calculation, variation was completely removed from the equation.

When we simulated target inventory calculation as above mentioned for components and target for all finished goods, we calculated an overall decrease of 50% for the component inventory and a 417% increase for the product inventory. Overall investment value would then be increased by close to 9 million euros. Clearly this result demonstrates that when comparing the two extremes of our inventory positioning. Coupling point should remain in the component inventory, but in addition to these two simulations, we also wanted to test the inventory model where we could decouple as much demand variation for purchased components as possible by placing finished good stock for only a few products. These products where selected by comparing how big of a share each individual product contained from the total production volume. We discovered that only 12 products from the total 168 comprised 50% of the total volume. These products are so called “runners” as they are purchased with a very high frequency by our customers.

Product ID	Percentage of the total production volume	Demand variation
Product 1	8 %	13 %
Product 2	16 %	20 %
Product 3	23 %	22 %
Product 4	29 %	28 %
Product 5	35 %	42 %
Product 6	38 %	23 %
Product 7	41 %	29 %
Product 8	43 %	6 %
Product 9	46 %	53 %
Product 10	48 %	34 %
Product 11	49 %	73 %
Product 12	51 %	35 %
		32 %

Table 2: Product volume allocation.

Runner categorization for the stocked products also minimizes the risk of obsolete inventory. With high runner products we can be fairly sure that the finished good inventory will be consumed since the life-cycle of and volume for such products is much more transparent than with rarely ordered products.

We calculated new inventory target values for finished products and components by assuming that the demand fluctuation with these twelve selected products presented would be completely removed from component demands. We also assumed that since these twelve products comprise half of the overall production volume, we could divide the average demand variation for these products by half and apply that reduction factor for all the components in our component inventory calculation model. In example:

- Component 1: Current demand variation = 6, simulated demand variation = 6 * 0,5
- Component 2: Current demand variation = 9, simulated demand variation = 9 * 0,5

Results for positioning inventory for the high volume products in addition to all components revealed that the overall inventory investment target would decrease by 2%, which is not a very drastic change from the current situation but by positioning the inventory as described we can achieve benefits that aren't achievable when our demand variation and demand variability is as high as previously stated. Such benefits could be for example:

- Improved delivery performance through reduced lead time for the high runner engines.
- Balanced production demand for 50% of the overall production volume
- Possibility to use Lean replenishment techniques (e.g. Kanban) for purchases through stabilized production demand.

4.4.3 Information systems

To study the effect of enterprise resource systems in controlling variety, we decided to look for literature on how improved technological systems such as ERP can improve the operational processes on our supply chain practices and especially on lead time performance. Most of the supply chain processes are controlled by ERP and the restrictions of ERP performance can significantly undermine the overall efficiency of our supply chain.

Peter Ward and Honggeng Zhou (2006, 1) have studied the impact of information technology integration and Lean practices have on lead time performance. They suggest that managers are challenged by how to balance resources for process improvements achieved through investments in lean practices and information technology deployment. Study confirms that implementing lean/Just In Time practices significantly reduces lead time, but also that these practices mediate the influence of IT integration. Even though companies gain success in reducing lead time through lean practice such as JIT, there are many benefits in IT integration practices such as those that are embodied in the enterprise resource planning system. IT integration refers to information that is electronically transmitted between companies.

Ward and Honggeng (2006, 6) studied the effects of both internal and external integration of IT but in order to limit the frame of reference we are going to focus on external integration benefits. Concept of information-enriched supply chain separates the lead time in two segments, lead time of material- and information moving in the supply chain. Companies engaging in information-enriched supply chain concept are more are more closely connected through reduced information lead time and thus are able to reduce the overall lead time in the supply chain. The study reveals that analytical studies provide evidence that between-firm IT integration can reduce lead time. For example sharing demand and inventory data can shorten the order processing lead time, which can lead to significant inventory reduction and in turn is associated with reduced lead times. More detailed introduction to Just in Time – concept in chapter 5.3.1.

4.4.4 Order quantity reduction

When working with high demand variability infused supply chain, order quantities have a significant role in reducing the inventory investment and the risks of disruptions to our supply chain. Order quantities are usually determined with economies of scale in mind, as higher one time purchases of certain components might significantly reduce the transport or transactional costs especially with intercontinental shipments. With the reduced number of purchases or call-offs from suppliers we could reduce costs on customs clearances and transport through higher load optimization degree. Although higher order quantities might bring benefits in transport and in order creation transactional costs, reducing the order quantities will cultivate benefits in other forms through improved material flow. Increased material flow will ultimately reduce for example our:

- Inventory investment
- Quality defects
- Lead time
- Obsolete inventory
- Warehousing costs
- Labor costs
- Delivery disruptions

These benefits are all derived from removing excess inventory as number of deliveries increase, our requirement for inventory incrementally decreases. In addition to reduced inventory we can also argue that the risk of supply will also decrease from decreased order quantities. Imagine a supplier that produces hundreds of parts to our company and has a limited production capacity. When we order larger quantities of parts at once, the production capacity is limited to producing only these parts. Can we be sure that these produced parts are exactly the parts we require at that point in time and what if the production demand shifts from one product to another? In the worst case our supplier could concentrate on producing and delivering the wrong parts at the wrong time. Another good example could be that we have ordered components from our intercontinental supplier by oversee container delivery. Call-offs are generated monthly and the transportation of a container will reach us after 6 weeks from the point of dispatch. What if the there's a problem with that one transport that holds a month worth of parts for our production? What would be the risk of disruption in case we had transports coming in weekly? Supply chain risks are difficult to measure by cost perspective and are rarely taken into account when deciding or quoting for the appropriate order quantity from our suppliers but nonetheless are a very important factor to consider.

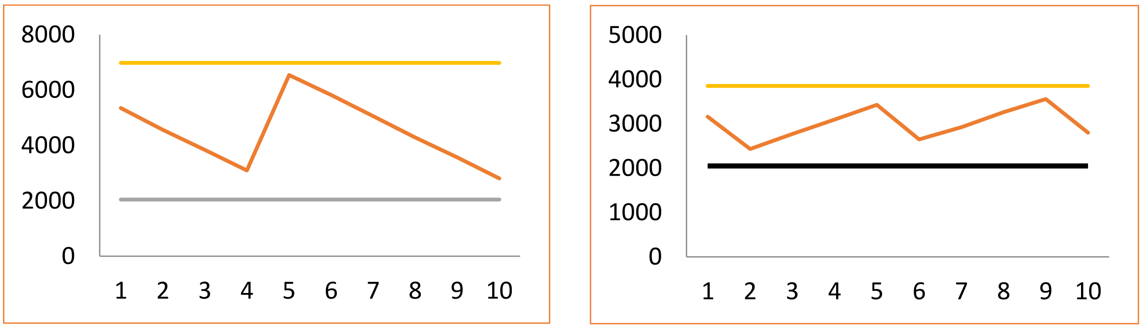

Figure 12: Material flow increase by order quantity reduction.

In the figure 12 we have simulated the inventory fluctuations of a single component sourced from our oversee supplier. With the overall lead time of more than 12 weeks the requirement of inventory holding is very high. Currently the agreed minimum order quantity is at 4200 pieces and we can observe how our inventory fluctuates with this order quantity in the first (1.) graph. Upcoming deliveries are consumed approximately in a 6 week period until the next shipment comes in. Minimum inventory is set at 2000 pieces and the maximum inventory will reach as high as 7000 pieces. In the second graph (2.) we have simulated the inventory fluctuations with four times lower order quantity (1050 pcs), which is equivalent of 1,5 weeks of demand. In this graph the minimum stock quantity is set also at 2000 pcs as in the previous graph (1.) but the maximum inventory would decrease by more than 3000 pcs. This drop in maximum inventory will decrease the average stock value by 34% which is close to 22 000€. This only demonstrates the cost reduction effect increased material flow has on our inventory investment but it also shows that the benefits in that area are substantial.

5 Removing waste with LEAN SCM techniques

5.1 Knowledge framework

Since the integration of Lean philosophy into supply chain management practices, decision making has been a challenge because of the complexity, dynamics and uncertainty inherent to supply networks and types of waste. Liu, Leat, Moizer, Megicks and Kasturatne (2012, 1) have proposed a decision-focused knowledge framework that can provide an efficient and effective support for collaborative decision making for eliminating waste in the supply chain. Waste is characterized as any process that requires the use of resources and in turn doesn't add value to the customer.

Collaborative decision making in supply chain management can be a difficult practice to engage upon, but the benefits are hard to argue against. Many of the day-to-day business decision we embark on are based on single or narrow perspective of the supply chain management and although they might be effective and create value for our organization the total customer perceived value might be much lower due to complexities in our supply chain management. Collaborative decision making is of course a straining process and quick actions don't usually occur, but a collaborative decision making framework allows us to advance into a more broadminded approach in our day-to-day decisions (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 1).

In the study a decision-focused knowledge management framework has been proposed to address the knowledge support requirement for collaborative decision making in lean SCM (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 4).

5.1.1 A7 x 4 knowledge model

Knowledge model introduced in the study shows the seven types of waste and knowledge factors related to removing them (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 5).

- Know-what: Solutions and problems are explained and defined through facts.
- Know-how: How are we able to accomplish waste elimination.
- Know-why: Why waste elimination is required.

- Know-with: How removing waste relates to other types of waste. Removing waste shouldn't have a negative effect on other types of waste.

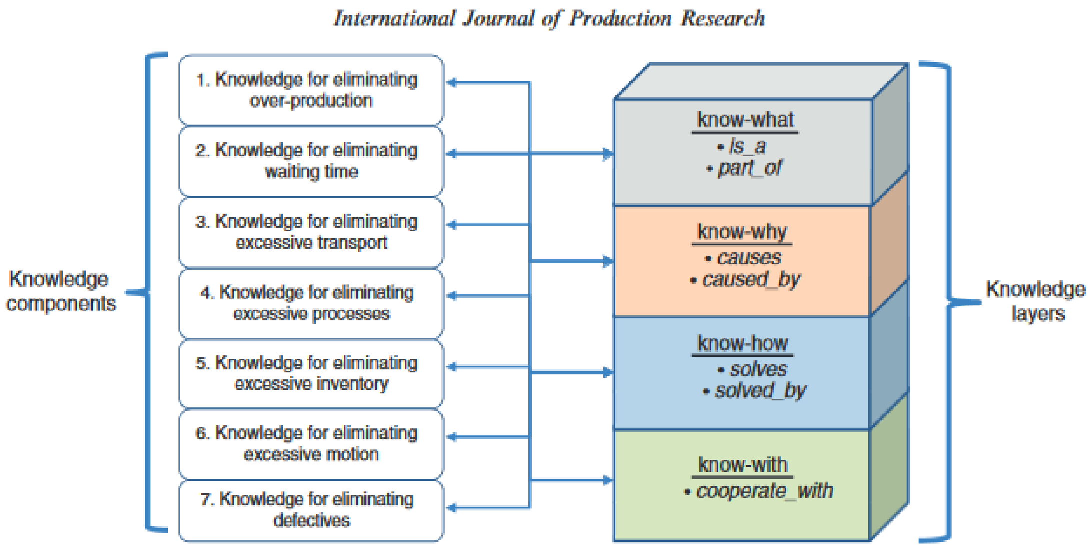

Figure 13: Waste elimination knowledge model (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 5).

After introducing the knowledge model for collaborative decision making and explaining the knowledge factors Liu, Leat, Moizer, Megicks and Kasturatne (2012, 6) have developed a decision tree for the supply chain waste elimination knowledge base in order to better understand the knowledge support factors for effective collaborative decision making.

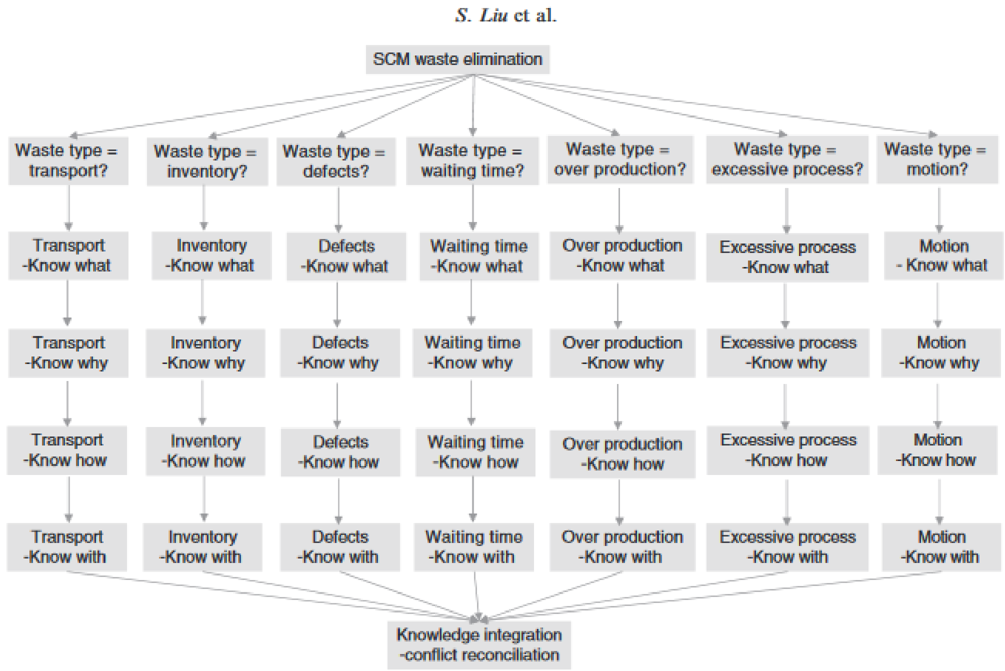

Figure 14: Decision tree for lean supply chain elimination knowledge base (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 7).

This framework provides us with an effective tool for informed decision making in the supply chain waste elimination and should be applied whenever a company is engaging in waste elimination activities in SCM (Liu, Leat, Moizer, Megicks & Kasturatne 2012, 7).

5.1.2 Kaizen principles in the supply chain

Kaizen is part of the widely known lean management method and as a concept it is today implemented in many organizations worldwide. The word kaizen comes from Japanese language and it can be translated into “change for better” or “improvement”. Toyota first introduced lean management method and kaizen principle in order gain competitive edge in automotive industry after World War II and after more than 60 years ago companies are still learning ways to implement these methods into their business, no matter the industry (Coimbra 2013, 3).

In this thesis I hope to bring insight to kaizen principles in supply chain management and how it could be managed in our supply chain operations in order to gain improvements in visibility, waste elimination and material flow. Kaizen method of course encompasses much more but I want to limit my research to these three factors in supply chain management.

As mentioned before kaizen was developed by Toyota Motor Company and was applied to all its supply chains. Kaizen operation model is designed to create a flow of materials and information that is pulled from actual customer orders. Material flow throughout the supply chain should be then designed to react to actual customer demand rather than expected customer demand (Coimbra 2013, 4).

Coimbra (2013, 6) describes this method as a pull-flow paradigm. When consumers buy products or materials from retail stores or producers, they "pull" materials. As a result of customer pull, retail stores or producers should then pull materials from their suppliers and the manufacturing companies should then simultaneously pull materials from their suppliers and so forth. That is what Toyota put to practice in all its supply chains from car dealerships to all its suppliers. In order to achieve pull-flow all relevant stakeholders in the supply chain need to have an extensive commitment to kaizen principles, which can categorized as (Coimbra 2013, 6):

- Quality first
- Gemba orientation
- Waste elimination
- People development
- Visual standards
- Process and results
- Pull-flow thinking

5.1.2.1 Waste elimination

Waste elimination is considered to be the first pull-flow related principle. Coimbra (2013, 8) has defined seven different forms of waste and by eliminating these forms of waste in the operations we are able to achieve competitiveness and excellence. These seven waste factors are categorized as follows:

1. Defects
2. People waiting
3. People moving
4. Too much processing
5. Material waiting
6. Material moving
7. Overproduction

Coimbra (2013, 9) also brings up the three M's which are "muda", "mura" and "muri". These types of waste can be found in most of the lean literature and these words can be translated into “waste”, “variability” and “too difficult”. These three M’s usually exist together (Coimbra 2013, 9).

As we have discovered when variability exists in the process or system, managing that process becomes difficult and almost always results in waste. On the other hand if we review our processes through how much waste there exists, we usually find that they also contain the most variability.

In the field of logistics the fifth form of waste is most commonly recognized. Material waiting, material is standing still and not being used. This is an obvious form of waste and also called stock. Generally it is astonishing how accepted stock keeping is still in today’s business and especially in the manufacturing industry. Stock is a form of buffer against other unwanted difficulties that exist in our business processes. In case we have many different products and customer needs are difficult to forecast. Then in order stabilize our production, company could keep raw material stock in order to combat poor production planning. Stock and how large it is, is a result of prevailing conditions in our processes (Coimbra 2013, 9).

Figure 15: Sea of inventory (Oweisi 2016, 2).

Second important form of waste is material moving. Whenever we are transporting materials it adds no value for our product. Transportation is often considered as necessity and for that reason not easily accepted as waste. Of course as long as products require raw materials that can’t be produced at close proximity of our manufacturing, transporting them is necessary but it should of course be considered as waste in order to find new solutions or improvements to reduce the need for it (Coimbra 2013, 10).

Third important form of waste is overproduction and it can be a result of error in forecasting of companies customer demand and production capacity. Overproduction is a result of an opposite form of strategy than pull-flow. We tend to “push” products in order to avoid problems in our supply chain and manufacturing (Coimbra 2013, 10).

Common factor in all these three forms of wastes is the general difficulty in accepting them as waste. They are considered necessary in order to meet customer needs and economical manufacturing. In many companies it is even common that we create KPI’s that support the need for stock, overproduction and transportation (Coimbra 2013, 9).

As Abdulkareem Oweisi (2016, 2) explains is his text “Isn't it Obvious? TOC and Lean main goal is to increase throughput not to reduce costs!!” our focus should be to increase throughput throughout our supply chain rather than optimize costs, although it is extremely difficult to measure cost benefits that result from increasing throughput most companies have gained just that by doing so.

5.1.2.2 Visual standards

Picture is worth a thousand words and there’s no better way of performing a task than standard, explains Coimbra (2013, 11). We can all endorse especially the first expression that seeing is better for understanding. We even have a universal saying to ratify that, “I don’t believe it, until I see it”. It is much easier to comprehend tasks or problems when we have visual aids for support. Second proposition is much harder grasp, especially in our daily lives. We tend to measure our expertise in any task on how little we need instructions. It tells us that we are so good at what we are doing, that nobody needs to tell us how to do anything Coimbra (2013, 11).

From a process point of view this of course isn’t so favorable. In order to achieve balance in our operations we need enforce standards in our ways to work and how we perform tasks. This of course doesn’t rule out that we shouldn’t change the way we work if we know how to improve our daily routines. Rather than diverging from standards, we should continuously improve our standards. When we learn a way of improving our daily work, we should make that improvement a standard available for everyone.

5.1.2.3 Pull-flow thinking

Pull-flow principle encourages organizations to organize their supply chains in terms of optimal material- and information flow. In order to achieve in improving our material- and information flows, we must focus on removing material waiting, or inventory. Improved material flow drives for lower batch sizes in both manufacturing and purchasing, which on the other hand smoothens the material demand and improves our ability to plan production. With improved planning, inventories can be decreased without any supply disruptions to production or customers. Pull-flow thinking doesn't merely focus on improving material- and information flows, it also emphasizes on "pull", which means that in order to be efficient and avoid forecast inaccuracy driven excess inventory, we should only pull materials to production when the need is based on actual customer order Coimbra (2013, 12).

5.2 The structure of Kaizen in Logistics and Supply chain

Kaizen should be applied to an entire supply chain of a given company and the method for achieving it is total flow management. Total flow management model describes the total lead time of a company's supply chain and by gaining advances (reductions) on total lead time we can increase the flow of goods and information. Effective way to that is to first visualize the supply chain and the time it takes from materials to be produced into sellable goods. This is of course an effective way to reduce muda or material waiting, but material flow has also other favorable effects such as Coimbra suggests (2013, 15):

1. Reduced costs
2. Reduced working capital
3. Increased productivity
4. Improved quality
5. Higher levels of customer service and satisfaction

Waste is present in every stage of our supply chain and we tend to concentrate our focus on the waste that has an immediate effect on the costs of our organization by moving it downstream to our suppliers or maybe even inside the own operations. This doesn’t remove the waste and doesn’t make our operations more cost effective if it doesn’t decrease the total lead time of supply chain.

That is the reason why total lead time is such a good measure to track the overall capability of our supply chains, but it also creates unpresented challenges. Supply chains form of many different stake holders and by achieving a reduced lead time, all stake holders should aim to for the same target Coimbra (2013, 15).

5.3 Optimized mix of pull and push principles for supply network

Automotive industry has always been a forerunner in optimizing their logistics cost and improving the performance of inbound processes through new and innovative techniques. One of the most widely known, adopted and practiced principle is Just-in-time. JIT logistics ensures that all the elements in the supply network are synchronized. With optimized pull and push techniques it is possible to significantly improve the cost effectiveness of inbound processes (Klug 2016, 1).

5.3.1 JIT concept

Push system in supply network is a schedule driven concept that uses a centralized approach designed to calculate the demand. Centralized approach takes pull-driven demand from customers and uses a centralized planning function to transfer demand into a production schedule (Klug 2016, 1).

Master production schedule is designed to produce products to match customer demand. Production planning function uses the available demand information to in order to optimize capacity use and ensure mix-model production. Production schedule is then converted into individual component or material requirements. Production schedule follows a specific fixed-period rule which is set as low as two weeks. Customers are allowed to change their demand forecast information to some extent, within agreed parameters but when the production requested delivery quantity reaches the fixed-period it will be considered as unchanged. JIT concept allows us to pull components from suppliers at the exact time, at the exact quantity. In AGCO Power this could be achieved by integrating supply networks into our production schedule demand information and requesting call-offs on the basis of that information. In order to be successful in requesting the right quantities at the right time, we must be sure that the production schedule remains unchanged after the call-offs have been made.

5.3.2 JIS concept

JIS or just-in-sequence concept is based on requesting and delivering components from suppliers at the exact sequence as the production schedule, also called as the "pearl necklace" – concept. Production schedule is arranged in the exact production order by a single engine. In the JIS concept external supplier call-offs should be created at the beginning of "frozen zone" as where pre-determined production order should remain unchanged (Klug 2016, 3).

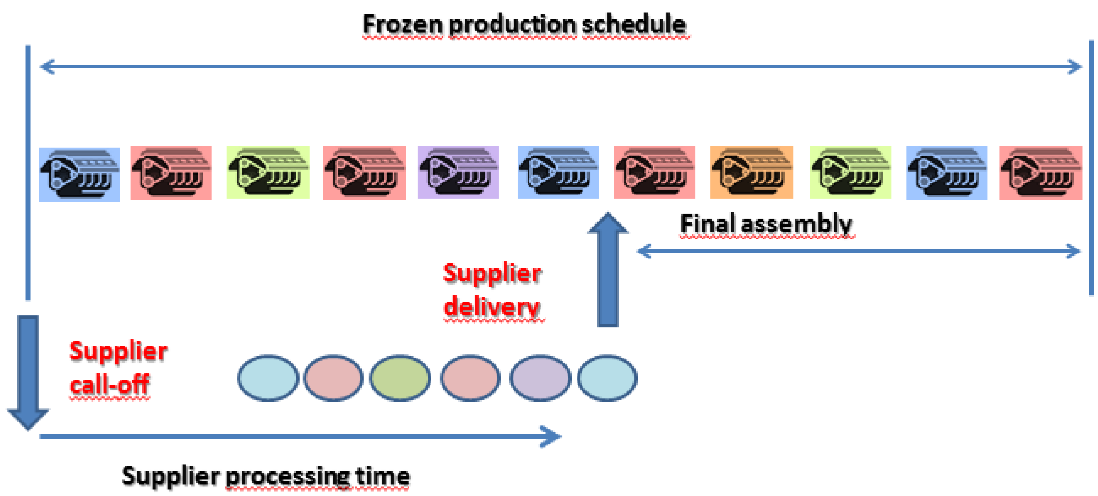

Figure 16: Hypothetical JIS supply process in AGCO Power.

6 Balancing manufacturing and demand forecasts

6.1 Lean repetitive flexible supply

"Lean repetitive flexible supply can be best conceptualized through a jigsaw puzzle". Glenday, Sather and Jones (2013, 11) describe the process of production planning as a form of compiling a jigsaw puzzle again and again where jigsaw puzzle pieces represent the produced products. Whenever a production plan is formed it's equivalent to putting all jigsaw puzzle pieces into a bag, shaking it and compiling the puzzle from scratch. This process is then repeated every time our production plan needs to change, which may lead to corporate “firefighting”. They also mention that when solving a jigsaw puzzle we most commonly set the corner pieces and straight edges first in order to give structure to the puzzle, thus making it easier to find correct places for the center pieces. Lean repetitive flexible supply suggest that in most of the manufacturing companies these so-called corner pieces and straight edges remain the same each time we build our production plan or schedule. These pieces are described as runner products (high volume products) that are produced regardless how we decide to compile our production plan because they represent such a high portion of our sales. What if these runner products or corner pieces in our puzzle could be left in place every time we build our production plan? Would that make production planning easier, faster and more efficient? Many would certainly agree that it is so.

In AGCO Power we decided to analyze our products through customer demand and production output and recognized that more than 50 percent of our production volume is created by 10 products, although these 10 products represent only 6% of our total products in quantity. By balancing the production of these ten products our production plan “puzzle” would be half done every time it needs to rebuild. This strategic decision would of course also mean that we would need to build a buffer stock for each of these products in order to effectively dampen the variations in customer demand while maintaining a steady and balanced production for the products. Usually every business improvement effort tends to remove stocks rather than creating them. Why would create a stock where it wasn’t needed before? Is a very valid question and let’s analyze the reasons behind this strategic decision. We already know that these ten products have the highest customer demands from all the rest of the products so the risk of obsolete inventory is fairly minimal. Also because of the high volume we know that shipments to customer are regular, which also allows us to have low inventory due to high inventory turn rate. The most compelling reason behind such decision is nonetheless the dampening of production variation that balanced production of these engines allows. When variation exist in production our planning is much harder as previously explained and as a result also our purchasing of components comes equally difficult. When production volumes vary, we must keep inventory of components in order cope with changing production demand.

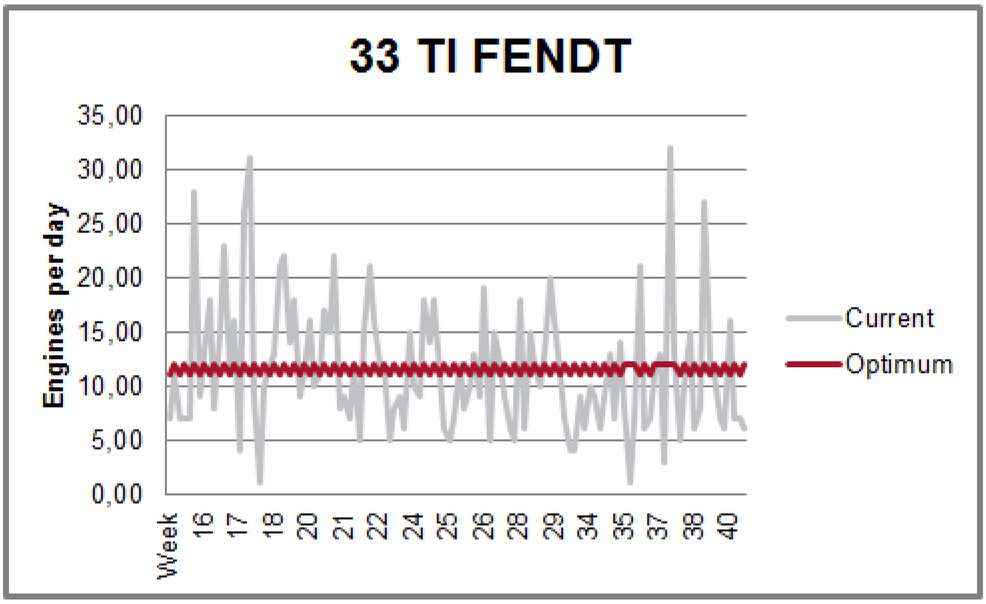

Figure 17: 33 TI engine model production volumes 2016 (1 engine variant).

In the figure 17 above you see the production volumes of certain high runner product from week 16 to 40 in 2016. We can clearly see that there’s a high variation in weekly production volumes. Imagine that there’s a change in customer demand and we would need to adjust the production plan so that the high volumes during week 37 would need to be produced one week or few days earlier in order to service our customers in time. That wouldn’t really have a positive effect on our production planning and purchasing.

6.1.1 Case AGCO: Balancing production plan with high volume engines

In order reduce the demand variation to our component purchasing we decided to balance the production plan forecast with few high volume engine models. The first model we decided to balance was the same 3-cylinder engine model seen in the figure 17. Plan was to start balancing the customer forecast at the beginning of 2017 since usually the stock value targets are the lowest at the end of the year. In practice it meant that we changed the customer forecast to reflect average demand, rather than actual demand. AGCO Power supply and planning delivery manager Ilkka Tuovinen changed the production strategy with this particular product into build to stock – model, and the engine stock was planned to fluctuate within dynamic minimum and maximum values depending on the average demand. Finished good stock was built during the first four production weeks of 2017. Finished stock then allowed Ilkka to balance the production plan into equal production quantities for the product several weeks ahead. As we can see from table 3 from week 6 onwards the master production schedule has remained unchained and the schedule is very balanced when considering the planned production quantities. In theory this should have allowed us to plan equally balanced delivery schedules into our suppliers and the supply risk as well as “firefighting” should have been very minimal.

	Forecast W2	Forecast W3	Forecast W4	Forecast W5	Forecast W6	Forecast W7	Forecast W8	Forecast W9	Forecast W10	Forecast W11	Forecast W12	Forecast W13	Forecast W14	Produced engines	Diff. From planned qnt.
Plan W2	58													95	64 %
Plan W3	58	58												47	-19 %
Plan W4	58	58	58											51	-12 %
Plan W5	29	29	29	58										47	-19 %
Plan W6	29	29	29	58	62									60	-3 %
Plan W7	58	58	58	58	62	62								59	-5 %
Plan W8	58	58	58	58	62	62	62							51	-18 %
Plan W9	58	58	58	58	62	62	62	62						33	-47 %
Plan W10	58	58	58	58	62	62	62	62	62					60	-3 %
Plan W11	58	58	58	58	62	62	62	62	62	62				63	2 %
Plan W12	58	58	58	58	62	62	62	62	62	62	62			60	-3 %
Plan W13	72	72	58	58	62	62	62	62	62	62	62	62		62	0 %
Plan W14	36	36	58	58	62	62	62	62	62	62	62	62	62	97	56 %
Plan W15	54	54	58	58	62	62	62	62	62	62	62	62	62	55	-11 %
Plan W16	72	72	58	58	62	62	62	62	62	62	62	62	62	39	-37 %
Plan W17	54	54	54	58	52	52	52	52	52	52	52	52	52	76	46 %
Plan W18	54	54	54	58	52	52	52	52	52	52	52	52	52	76	46 %
Plan W19	72	72	72	58	52	52	52	52	52	52	52	52	52	62	19 %
Std. Deviation	12	12	10	0	4	4	4	4	5	5	5	5	5	16	
											Total W14-W19		342	405	18 %
											Total W2-W13		728	688	-5 %
												Total	1070	1093	2 %

Table 3: 33 model master production schedule vs. actual produced quantities.

Table 3 also demonstrates that forecasted production quantities don’t reflect the actual produced quantities for model 33. Difference between the produced quantities and forecasted quantities can be up to 56%. Nonetheless total produced quantity within the 17 week period is approximately the same as the combined forecasted quantities. With a more detailed investigation to the production planning we learned that the difference in what was planned and actually produced was caused by poor production efficiency. Problems in production caused a backlog in production that lasted throughout Q1, 2017. This is clearly visible when observing the production volumes of model 33 during weeks 3 to 12. From week 14 we can see a significant increase in weekly production quantities.

Backlog doesn’t remove the demand for components but it can significantly increase our inventories. Strict inventory value targets might drive our material planners to cancel or postpone component deliveries in order to reduce their inventory value.

This is of course preferable if the production plan is adjusted to reflect the actual production capacity but as in this case we can see from table 3, production volumes remain the same although backlog is increasing. Postponing the delivery quantities and postponing the delivery lots might have a serious effect on material availability in case production is able to catch up with the production plan.

Uncertainty of the prevailing conditions that drive our supply chain activities still seem to be one of major concerns for our employees that work in operative purchasing or supply planning & delivery departments. Information doesn’t reach all relevant parties across functions and decisions are made with insufficient knowledge of our day to day business. In order to manage our supply chain activities better we should increase cross-functional information sharing and make joint decisions on how to operate in different conditions. With better knowledge on when and how the backlog could be removed, we could accommodate our component inventories accordingly and give better insight to our customers about our current situation. When our business decisions are based on traditional “silo” thinking, it will eventually create exceptions and more firefighting.

7 Order management optimization

7.1 ABCD – and RRS - classification

Nada Sanders (2014, 23) explains ABC – classification as way to recognize where the importance of an inventory lie. Some items are important, some are less important and some have very little importance. Hope you don’t get me wrong, of course every component is relevant, since the absence of even one component can cripple the whole operation, but it’s relevant how much time and effort we should spend on keeping the stock at an optimal level. Classifying our inventory based on the degree of importance allows us to place more notice to where it is needed and also allows us not to waste precious resources where they aren’t needed.

According to Sanders (2014, 23) ABC classification is based on Pareto’s law and it states that a very small amount of items account most of the total value or spend.

AGCO Power uses four categories with its traditional ABC – analysis. ABCD – analysis allows AGCO Power to better recognize the extremely rarely used components. D category items hold 2 percent of the overall purchasing spend, but on the other hand cover more than 60 percent of the overall item count.

ABCD – analysis has been previously counted by using the rolling 12 month component consumption data, but consumption data doesn't reflect the latest customer demand, especially when data source period has been set for such long. Changes in demand are lagging behind for 12 months. Our experience showed that in order to reliably determine the order controlling method by using the ABCD – classification as a factor, we needed to first change the way ABCD – analysis is calculated. Analysis should be performed by using the forecast data, rather than the consumption data. Even though forecast data isn't nearly as accurate data source as consumption data, it helps us to better recognize what is the current category of a certain component.

In addition to ABCD – analyzing our items, we wanted evaluate how each item is used in our production. As previously mentioned some of D (ABCD-analysis) category items might represent a low spend value, but could still be critical for production since that certain item might be required in each possible engine build. With RRS – classification we are able to evaluate how steady flow (or consumption) each item hold and decide what is the appropriate control method for purchasing. In other words how much attention we should pay to a certain item.

A-C lass, key items, 2% of total nr. Of items, 50% of overall purchasing spend
B-C lass, important items, 5% of total nr. Of items, 30% of overall purchasing spend
C-C lass, important items, 25% of total nr. Of items, 18% of overall purchasing spend
D-C lass, important items, 68% of total nr. Of items, 2% of overall purchasing spend

	A	B	C	D
Runner	Expensive part Steady consumption Good predictability	Reasonable expensive part Steady consumption Good predictability	Reasonable cheap part Steady consumption Good predictability	Cheap part Steady consumption Good predictability
Repeater	Expensive part Varying consumption Reasonable predictability	Reasonable expensive part Varying consumption Reasonable predictability	Reasonable cheap part Varying consumption Reasonable predictability	Cheap part Varying consumption Reasonable predictability
Stranger	Expensive part Irregular consumption Poor predictability	Reasonable expensive part Irregular consumption Poor predictability	Reasonable cheap part Irregular consumption Poor predictability	Cheap part Irregular consumption Poor predictability

Figure 18: Item analysis and classification.

7.1.1 Order handling categories

With the help of ABCD – and RRS – analysis we were able to create an order handling strategy that was based on our item classification. Items that represent high spend and steady consumption we want to optimize and create as lean material flow as possible. On the other hand for the cheap irregular consumption items we want to create more automatic ordering processes and possible increase safety stocks due to poor predictability of demand.

LONG LEAD TIME (transportation + lead time > 2 working days)

	A	B	C	D
RUNNER	MRP	MRP	MRP	KANBAN
REPEATER	MRP	MRP	MRP	KANBAN
STRANGER	MRP	MRP	ORDER POINT	ORDER POINT

SHORT LEAD TIME (transportation + lead time < 6 working days)

	A	B	C	D
RUNNER	JIT	JIT	JIT	JIT
REPEATER	JIT	JIT	JIT	JIT
STRANGER	JIT	JIT	JIT	JIT

SHORT LEAD TIME (transportation + lead time < 1 day and same supplier for all items within prod. line specific component family)

	A	B	C	D
RUNNER	JIS	JIS	JIS	JIS
REPEATER	JIS	JIS	JIS	JIS
STRANGER	JIS	JIS	JIS	JIS

Figure 19: Order handling categories.

Overall our strategy showed that there are only four categories where we should use different inventory control method than MRP and those categories all represent the low purchasing spend categories. Kanban and order point are both very automatic processes and don’t require much inventory control for the purchasing function. Although order point method have a tendency to increase inventory, that increase doesn’t amount to much in invested capital since both of these categories hold only cheap or reasonably cheap items. Both of these “more automatic” order inventory controlling methods ignore the effect of customer demand forecast and orders are only created when stock reaches a certain predetermined level. These stock level parameters are usually manually calculated and are usually based on the highest possible demand that production might require. In turn the MRP considers future demand and upcoming deliveries are accordingly calculated to respond the upcoming production demand. Even with runner items that have the steadiest consumption of all items, some demand fluctuation can be expected due to demand seasonality or product life-cycles and in case we want our inventory to reflect the present demand with the lowest possible invested capital and with the lowest possible work effort, this is most suitable strategy in our business environment to date.

	% of item total
MRP	40 %
KANBAN	30 %
ORDER POINT	30 %

Figure 20: Items in different order handling categories.

7.2 Plan for every part (PFEP)

Lean and continuous improvement is part of our everyday business activities and in order to achieve truly lean material flow throughout the organization we must improve our continuous flow not only in production but in the whole supply chain. More and more companies are making headway by progressing in continuous flow areas within the production as managers learn about value-stream mapping and continuous flow cells but have trouble sustaining steady output. The problem can be that although companies are engaging in lean activities in the area of production, same activities haven't been implemented in the supporting functions such as purchasing (Harris 2004, 1).

As in our organization, lean material handling activities are implemented in small areas of our operations and the removed waste such as material moving is moved rather than removed to a downward stage of the supply chain. Material management extends throughout the supply chain and our focus should be in creating a system that visualizes material flow in the entire supply chain and reacts to changing conditions so we are constantly able to set our operations with most optimal way. In most cases it is impossible due to availability of information, but within the organization required information is available, just not utilized.

Lack of such door-to-door lean material handling system for purchased parts can result in starvation of processes, loss of flow and major waste of effort and money (Harris 2004, 1).

In order for our organization to create such system we need to possess complete supply information from every purchased part. How and where the part is sourced. How it is transported and stored. How it is replenished to production. And most importantly this information needs to be correct and up to date.

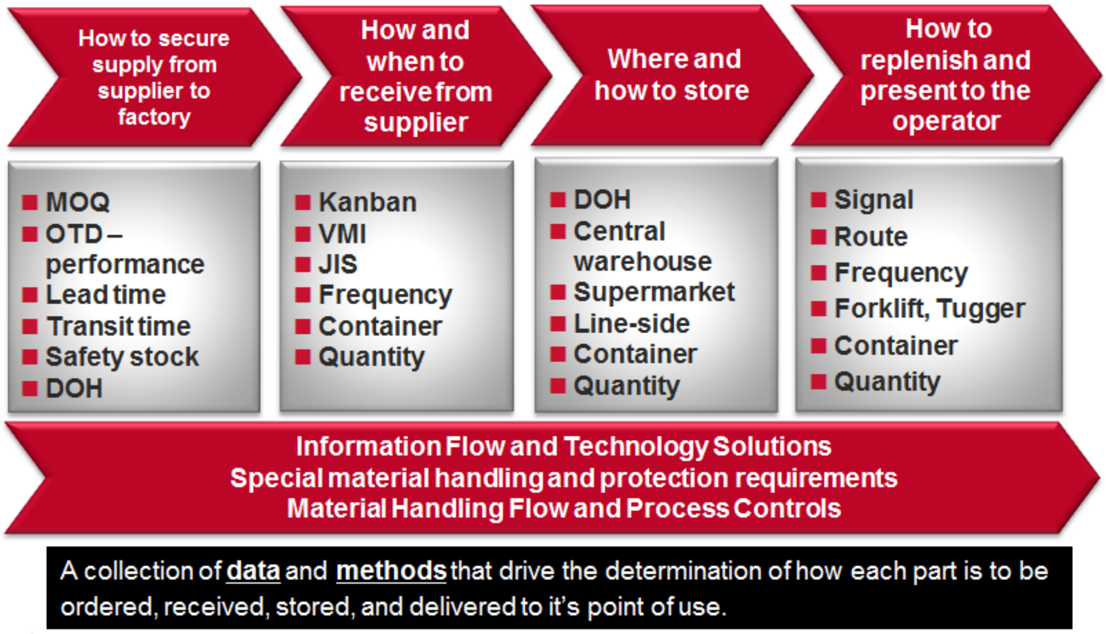

Figure 21: PFEP information and construction (AGCO).

This supply information framework can be achieved by creating a plan for every part that engulfs all our supply data (figure 21). Once PFEP is carefully established and properly maintained with accurate information Chris Harris (2004, 6) explains that it enables us to:

- Start creating a lean material-handling system that develops our in-house material flows
- Store viable data in one accessible and visual location
- Extend the material-handling system to our plant – to – plant material movements

More importantly PFEP enables us to align our complete material flow functions within the company and avoid waste causing properties within the flow. With properly functioning PFEP, introducing new lean material handling processes anywhere in the flow enables us to see the changes required for the entire material flow from supplier to production. In case customer demand increases for a certain material, we might need to change material handling processes and increase our inventory target and in case our in-house material replenishment processes change, we might need to change how and where the material is stored (Harris 2004, 6).

PFEP not only allows us to develop our material handling activities in-house but it can be utilized in our material purchasing activities as well. In AGCO Power we decided to take the system one step further and also extend the reach of such material flow optimization tool into our operational purchasing. We realized that in order to achieve a lean material flow, we would also need to align our material planning methods from supplier to our company depending on the prevailing replenishment methods we have in place in-house. For example if certain components are delivered in sequence into our production line our goal would be to acquire materials from our supplier(s) in sequence as well. This could be achieved if all relevant (single item group) components are sourced from single supplier (see chapter 4.2.5 for more details).

With the optimization tool we are not only able to control our logistics processes but we are also able to set targets for our component inventories, which in my opinion is the most important achievement of the system. By setting the inventory targets based on accurate supply information we are able to tell our operative purchasers how much inventory is required for each purchased part and of course set accurate safety levels into our material requirement planning system. By constantly analyzing our future demand and demand deviation we can set goals for inventory and unlike before we actually visualize how much inventory is needed to ensure required service level for production. Most importantly we can see the changes in our material flow and material demand and adapting to those changes instantly allows us to be pro-active rather than reactive.

7.2.1 Visualization of order management

Order management visualization was the first step in creating a functional plan for every part. We wanted to visualize how much inventory is actually needed for each item and how inventory would change in the upcoming days and weeks, in order to service our production with purchased parts without interruptions. Previously our order management created inventory targets solely depending on purchasers experience and gut-feeling, since our organization hadn’t engaged in developing mathematical models for inventory calculation previously and we needed to create a suitable model from scratch. Without actual targets for inventory it was impossible to determine if we had too much or too little inventory. The only indicator to measure our inventory was to track the weekly production schedule and compare our inventory against that demand. With lead times expanding to 4 months it was vital to get better visibility into our inventory and predict the problems in availability well in advance.

Inventory can be represented with an asset-liability curve that shows where inventory can be seen as an asset and when it becomes a liability (Ptak & Smith 2011, 406).

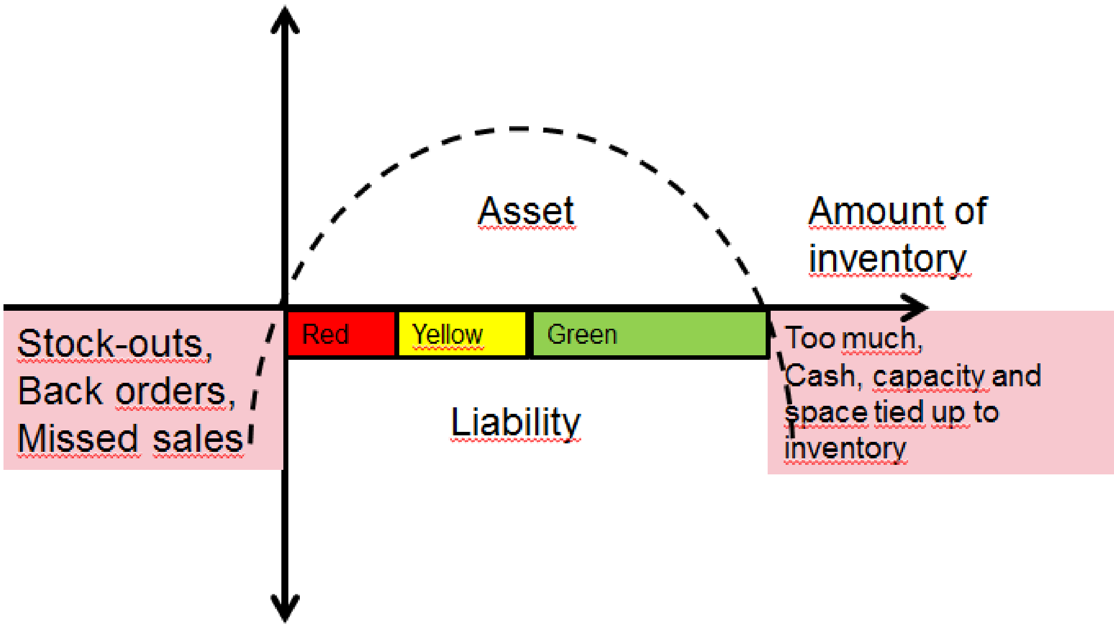

Figure 22: Asset-liability curve (Ptak & Smith. 2011, 406).

The X-axis represents the amount of inventory we currently have in stock and the Y-axis determines whether that amount of inventory can be seen as an asset or liability. Inventory can be seen as an asset as long as we have some inventory and we don't have too much of it. Most often companies inventory shifts between these two extremes and there's no visibility between them. How can we visualize our inventory in a way that our order management personnel or managers are able to react to delivery scheduling before our inventory slips into one the two above mentioned extremes (Ptak & Smith. 2011, 406).

Carol. A. Ptak and Chad Smith (2011, 407) addressed this problem by creating buffer profiles for each purchased item. Color of the buffer zone represents criticality of the stock. Buffer zones are one way to visualize the order management and inventory, with clear targets and visual way to represent those targets planners can easily spot when their attention to inventory and upcoming deliveries is needed.

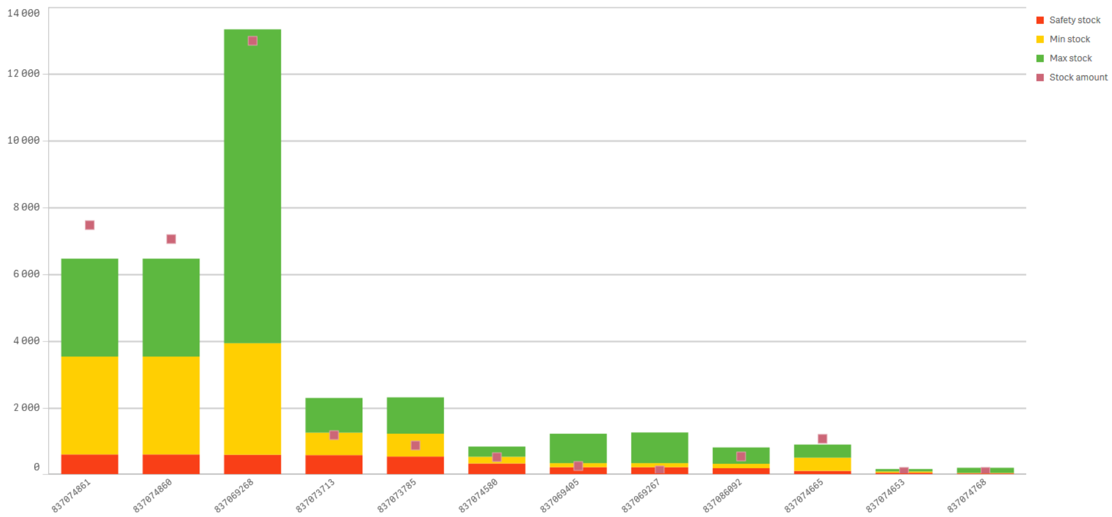

Figure 23: Current inventory situation (One column represents one item and the red dot represents current inventory situation in relation to different stock levels).

As we can see from the figure 23 current inventory situation is represented in three colors green, yellow and red. Green zone is where the stock should be at all times and the yellow and red zones represent the criticality of an inventory position. Red zone is the most critical and when stock quantity reaches the red zone it means that the stock quantity is already reached under the safety stock barrier and should be treated as critical. This figure is a good example on how inventory usually shifts between critical stock quantity (too low) and excess stock (too high). Out of twelve items in this graph there are only four items, which had green inventory buffers at the time. This means that the rest 8 items (66%) have inventories that should generate an alarm or exception and should be paid attention to. Most often this situation is a result of an assumption that more inventory should be kept with high runner items due to high volumes and low inventory with low volume items such as in the category stranger, but since most of the low volume items are consumed erratically, meaning they have high demand variation. These are the items for which we should keep higher inventories due to high demand unpredictability and focus on keeping lower inventories with the high volume, high priced items. High volume items have low demand variability because they are used in most or all of the products sold and forecasting inaccuracy isn't much of problem for such items. But with low volume products, production scheduling is a much more challenging task and the production demand might drastically change even with a slight re-adjustment of customer demand. For these items we should try to dampen the demand variation with inventory unless we are certain that forecasting is accurate and will remain unchanged.

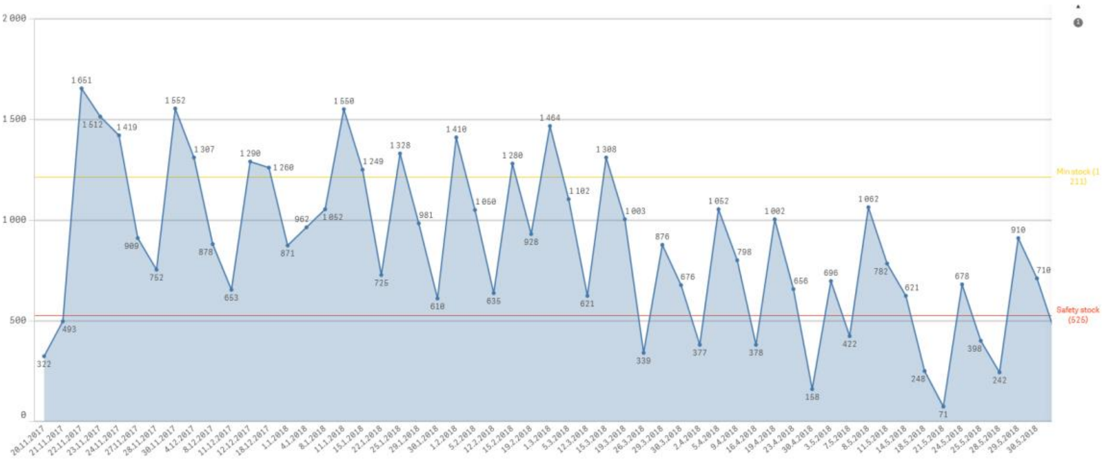

Figure 24: Future inventory development (Stock count fluctuations in time).

We didn't just want to visualize the current inventory situation but also what it will be in the future. This particular item is one of the high volume items but as you can see from the graph, its inventory fluctuates between minimum stock quantity (yellow zone) and safety stock quantity (red zone). Mostly we seem to have enough stock to service our production without stock-outs in short term, but as you can see in May 2018 we are very close to running out of components entirely. What If the customer demand increases even a little, would we then have enough stock or would we run out of parts completely. I would bet on the latter option. All and all this schedule shows a very pessimistic view on how our sales are expected to progress in the future. It looks like the purchase deliveries have been designed in mind that we will rather lose sales than gain them. It is like we are betting against our own forecast which can be very dangerous especially with the more complicated components that have long lead times. Suppliers also predict their purchases based on our forecast and if they decide also to bet against our forecast, we might experience serious problems in our supply chain during 2018.

7.2.2 Inventory targets

To able to visualize how much inventory is actually needed, we of course needed to calculate inventory targets for each item. Even though our inventory levels are represented in a minimum – maximum values, it doesn't mean that purchases are triggered as the traditional min-max method assumes. Controlling our inventory in this sense would create very high excess inventory, due to long lead times of our suppliers. Since we are creating an inventory model for our serial production materials, we know that the consumption of goods is constant and we don't need to wait for actual customer orders to create purchase orders. We use forecast based inventory fulfillment strategy and create delivery schedules with MRP that are based on our forecast of future consumption. Delivery schedules allow us plan much lower inventories and we don't need to take into account the long lead times of our suppliers, but the demand changes (demand variability) create problems for our production if we don't consider them in our inventory targets. From this starting position we created an inventory calculation model that constantly monitored our average forecasted demand and deviation in our consumption to able to set parameters for our delivery schedule creation. Our ERP system shows us the predicted inventory in point of time, based on the predicted consumption of materials and aligning our delivery schedules (predicted orders for our suppliers) with these parameters we can assume that we have enough inventory at hand although our production demand fluctuates and we aren't able to reliably forecast the fluctuations.

First we needed to set two constants for our model that are service level factor (1) and order processing time (2). Service level factor represents the availability percentage to production we want our inventory to achieve. Our goal was to have materials available for our production 95 percent of the time. With a higher service level our service level factor would be much higher (99%=2,326) (Uitto 2018, 1). Order processing time equals the time it takes to react to the changes in our demand / forecast. At the moment this changes depending on the supplier and in which order our material planners update their delivery schedules, but since all the delivery schedules are updated on a weekly basis it was safe to assume that all the demand changes would be noticed and communicated to the supplier within five working days.

1. K = Service level factor (95% service level = 1,64 factor)
2. Order processing time = 5 days

Safety stock:

$$K \times \text{Daily demand standard deviation} \times \sqrt{\text{lead time} + \text{transportation time} + \text{order processing time}}$$

Minimum stock quantity:

$$(\text{Average daily demand quantity} \times \text{order processing time}) + (\text{Daily demand standard deviation} \times \text{order processing time}) + \text{safety stock}$$

Maximum stock quantity:

$$\text{Average daily demand quantity} \times (\text{Average order interval} + \text{order processing time}) + \text{safety stock} + (2 \times (\text{Daily demand standard deviation} \times \text{order processing time}))$$

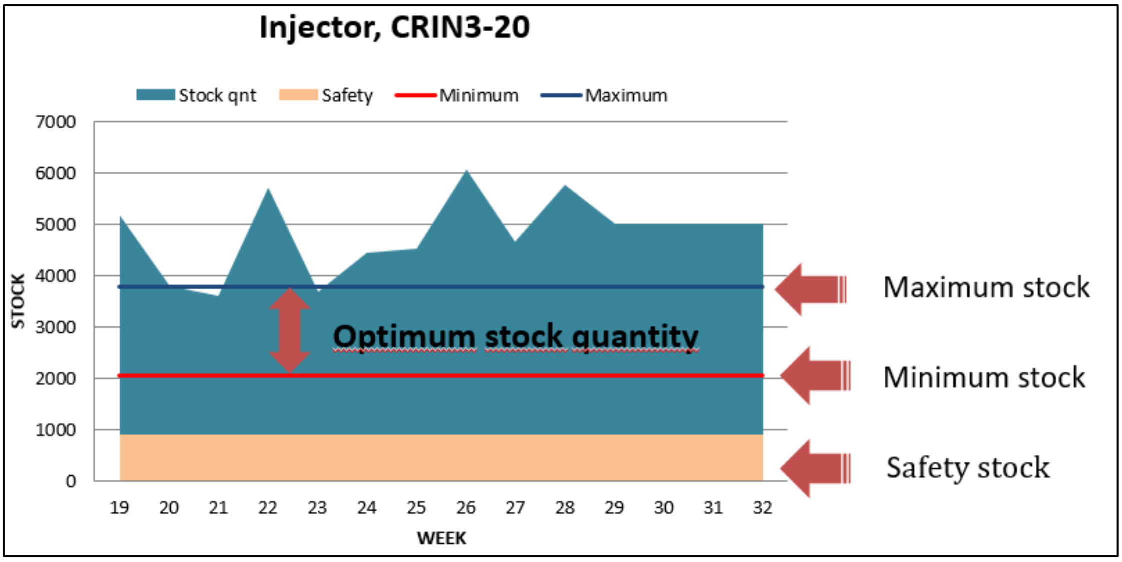

Figure 25: Inventory quantity prediction with calculated inventory parameters May 2017.

From the figure 25 it is easier grasp how these calculations aid us in planning our material purchases and how they should be considered in our planning process. This graph shows us a forecast on how our inventory of this particular injector will develop within the 13 weeks shown in the graph. As you can see our inventory will mainly fluctuate between 3800 pcs and 6000 pcs as it considers the upcoming deliveries from the latest delivery schedule and the predicted consumption from our latest forecast. From the calculation we have gathered that for this injector the daily demand standard deviation isn’t so high because this item is assembled to most of our engine models and keeping a high safety stock isn't necessary. For this reason the calculation suggest that the inventory should rather fluctuate between 2100 pcs and 3800 pcs instead. This means that each delivery should be planned to arrive when the predicted stock quantity is at the level of minimum stock and remaining 2100 pcs would still provide enough safety to service our production from demand fluctuations. It is also notable that the drop of average inventory we achieve by planning our deliveries according to these parameters is almost 200 000 €.

7.3 Standards and information

Correct and up to date information is the key for any sustainable process or such material management tool as PFEP. Plan for every part is designed to sustain our logistics processes and especially signal us of any changes required to our order handling parameters, before any problems should arise. This is of course not possible without correct information for which the decisions are based on. That is why in addition to a system that analyses information, we need processes that make sure our logistics related information is up to date. When I started to work on my thesis most of the supply related information in AGCO Power didn't have a steady update routine. Order management process is still mostly a manual task and most of the delivery schedule lines with dates and quantities are manually inputted and maintained in our ERP and with such manual working method. There wasn't really a need for accurate information on supply details. Supply details were stored in every planners mind through experience but without actual facts and certainty. There's always been a requirement for a more sophisticated ERP or ECC system in order to achieve more efficiency in the area of logistics. AGCO Power is currently working with a legacy system called Keybox, rather than SAP as most of the other AGCO sites, but during summer of 2018 AGCO Power will also implement SAP ERP into its operations. This of course at the same time created the need for more accurate supply information and we started to collect information with more resources and motivation than ever before. This was also very beneficial for the development of our material management tool PFEP.

7.3.1 Guidelines and data sheets

Variation comes in all forms and we shouldn't just limit our focus on product or demand variation, but attention should also be paid on how different stakeholders operate in our supply chain. Without clear standards to our suppliers, how to deliver parts, confirm delivery schedules or e.g. order materials we experience a lot of variation because of different working methods. Especially since only our Tier 1 suppliers expand to hundreds and are located all around the globe. Each supplier might a have slightly different standard on how to pack the parts and label the packaging units. It's is easy to grasp that in order to make wide and global supply chains more efficient we need to create operating or "service" standards for our suppliers and other third party service providers.

In AGCO Power logistics department we decided to standardize logistics processes related to shipping- and packing parts and also how to manage transport bookings, order handling and supply agreement information. These details were comprised into two separate guidelines called Logistics guideline and Packaging guideline. We introduced these guidelines into our supply network in spring 2017 and before that we had introduced them to few key suppliers. At the moment with suppliers that comprise 40% of our supplier spend have signed both guidelines. Our target was to standardize working methods for suppliers that comprise 90% of our total purchase spend, but we fall short of that target significantly. The task was much more challenging than first estimated.

As mentioned before information is as vital as standards, they both have a significant effect on our supply chain processes. Standards remove fluctuations and information is vital for planning optimized processes. In addition to guidelines AGCO corporation has two standard documents that are designed to collect information related to supply and it also acts as an agreement for supply details. Logistics- and Packaging data sheets were introduced into our supply network at the same time as guidelines, but most importantly we need make sure that the information we collect into these documents is always up to date. In order to make sure of that, these documents need to be included in our NPI process (new product introduction), Resourcing process and supplier audit process. In the worst case scenario having incorrect information might harm our supply chain more than having no information at all. At the moment AGCO Power has included these documents into NPI processes but we still need to make sure all resourcing activities include the collection of this information and that we have a steady update cycle for these files, in order detect changes in our suppliers supply flexibility and production capacity.

7.4 Optimized material flow and TCO

PFEP – tool can be used to provide inventory targets and in conjunction aid us to automate our order handling processes, but its main purpose is to control our processes in a way that we achieve optimized material flow. Optimized material flow is what we strive for and by achieving a lean material flow we gain the most efficiency from our processes. Waste can be found in every process within our supply chain and it is in a form of material - / people moving or material - / people waiting as previously explained in the chapter 5.1.2 Kaizen principles in the supply chain and with proper control of the processes we can eliminate some of the waste tied up to the system but ultimately with a properly functioning PFEP we can maintain our processes in a way that removed waste doesn't re-appear. In our company and as I would dare to say that in many other companies, we focus on improving our processes in form of project. Processes are redesigned and improved, productivity is gained and everybody's pleased, but the there's nothing to prevent that process from falling back to its original productivity value. In every process there are variables that change over time and if there aren't process controls that monitor these changes and react to them, it could very well be that in few years that improvement project that delivered value is worthless, if reassessed.

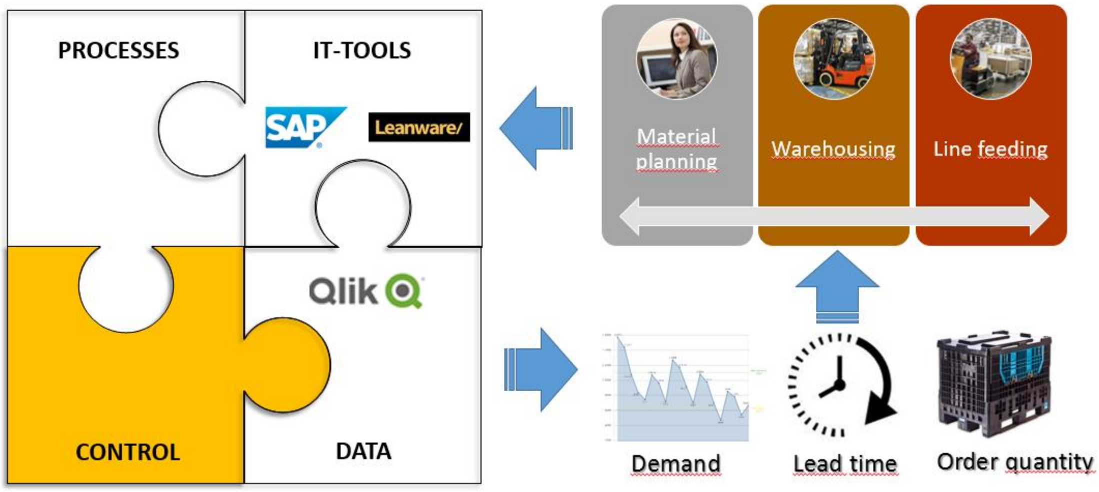

Figure 26: Process control with PFEP – tool.

Correct data is the building material for functioning plan for every part and by creating rules based on our standards we are able to constantly test our processes if they are aligned in the most optimized way according to the latest data available.

Most importantly with the data we are able to extract from our IT-tools we can monitor changes that have an effect into our processes and react to those changes in advance. This way we are able to control our processes pro-actively rather than re-actively. Possible problems are fixed before they are realized into actual problems.

7.4.1 Total cost of ownership

TCO - concept is a commonly used purchasing practice in today's global purchasing organizations and the abbreviation comes from words total cost of ownership. Goal is to evaluate purchases through all the costs related to the purchased good or service. Revealing all the costs related to a single purchase might be difficult or even impossible if the organization doesn't possess the right data to reveal such costs and that's the reason why in my experience TCO – practices have yet been implemented to smaller purchasing organizations that haven't got the resources to evaluate their purchases so extensively.

AGCO Power purchasing has only recently applied TCO – concept to aid in the organizations purchasing activities and the concept considers five (5) different aspects to product related ownership costs:

1. Component unit price
2. Product development costs

3. Quality related costs
4. Logistics costs
5. Warranty and aftermarket related costs

In the concept we have limited the evaluation time to 5 years in production and the end of a product life-cycle isn't included but still it is a major improvement on the purchasing evaluation and especially from a logistics perspective it has a big impact on how we look at purchases.

PFEP act as source for evaluating logistics costs and it considers the following factors:

1. Freight costs
2. Lead time (Supplier response and transportation time)
3. Warehousing costs (Costs of warehousing the amount of inventory required)
4. Average days on hand inventory (Amount of inventory due to lead time and supply risk)
5. Packaging costs (Special packaging costs due to supplier location)
6. Handling costs (Extra handling e.g. re-packing)
7. Supply risk related costs (Risk factor related to long lead time sourcing)

With the PFEP – tool we are able to provide purchasing actual figures related to inventory carrying and handling, but we are also able to constantly evaluate our logistics cost with current production components and how certain purchase price related aspects affect our logistics costs. Minimum order quantity is one of those aspects and it largely influences our ability achieve lean material flow. With better knowledge of how that reflects the logistics costs, we also have better bargaining power to influence minimum order quantity (MOQ) even though smaller purchasing batches usually mean larger unit prices.

8 Results and conclusions

As was our initial assumption, our company's supply chain design is a very challenging environment to manage and with this study we were able to shed light into the factors that drive these challenges and suggest actions that would allow us to significantly improve our processes and in conjunction manage our supply chain better. As with every structure or process, solid foundation is the key for success and if we are able to stabilize our supply chain environment, we are able to take advantage of the many tools out there to improve productivity of our supply chain processes as for example Kaizen principles imply.

What are then the factors that make our supply chain management so difficult? We established that our company is very flexible when it comes to product moderation and supply for our customers. Our competitive edge comes from offering tailored engine models with short lead times (serial production phase) and when this customer service strategy is combined with complex supply network and strict cost control, this equation becomes challenging. Our study then concluded that our supply chain environment is governed by the following factors.

1. High delivery flexibility (short lead time to customers)
2. High product variation (customer tailored products)
3. Complex and inflexible supply network (long component lead times)
4. High cost control for inventory value (Inventory cost reduction pressure constant)

We could change any of these factors to reduce challenges for our supply chain management but in order to keep our competitive edge our strategy remains to be flexible for our customers and source components from suppliers that offer world class technology and bring highest value for our products. Because of that our situation will remain challenging and we need to be smart and innovative when it comes to managing our supply chain processes.

8.1 Production balancing

From the staff interviews we concluded that most of the challenges experienced in our operational purchasing department can be derived from our master production schedule changes. Our material planners described that most of the workload comes from reacting to changes in customer demand and trying to align purchasing plans into that demand. These changes are especially challenging in near future and sometimes even impossible for our suppliers. How do we manage or get rid of these changes then?

As previously described in the beginning of 2017 (chapter 6.1 Lean repetitive flexible supply) we changed our MPS (master production schedule) with certain 3.3 liter engine to reflect average demand for every production week, rather than the actual customer demand and achieved a very stable production plan for this specific engine model. Gross requirement was set as average and evaluated time to time to check if the average demand remained within set limits. With this technique we were able to produce more stable component delivery schedules for our suppliers and reduce demand variation and bullwhip effect in return. Let’s take a look at one key components delivery schedule during weeks 11 to 20 during 2017.

	Production plan									
Delivery date	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
06.04.2017	140	100	100	100	100					
13.04.2017	120	100	120	120	120					
20.04.2017	120	100	120	120	120	120				
27.04.2017	120	120	120	140	140	140	140			
04.05.2017	120	120	120	120	140	140	140	140		
11.05.2017	120	120	140	140	140	140	140	140		
18.05.2017	120	140	140	140	140	140	140	140	140	140
25.05.2017	120	140	140	160	160	160	160	160	160	200
01.06.2017	120	120	120	140	140	140	140	140	140	140
08.06.2017	100	100	100	120	160	160	160	160	160	200
15.06.2017	100	100	100	100	100	100	100	120	120	120
22.06.2017	100	100	100	120	120	120	120	120	120	120
29.6.2017	100	100	120	160	160	160	160	160	160	160
Total W20 to W26	760	800	820	940	980	980	980	1000	1000	1080

Figure 27: Crankshaft delivery schedules during weeks 11 to 20.

This table shows us 10 different versions of delivery schedule that had been send to our supplier from week 11 to week 20 and the quantities are predicted purchase quantities we want our supplier to produce in a given week. Even though we balanced our production schedule with only one 3,3 liter engine model, that engine model comprised of more than half of the total volume within the engine size category and as we can see there are very little swings in demand quantities (exception highlighted with red borders). When demand swings from one extreme to another it’s very disrupting to our supply chain, but with this item we can observe that such swings are fairly minimum and the changes in demand are mainly related to increases. Demand has been rising steadily within these ten weeks and with each week our supplier has seen an increase in demand. This in itself is demanding for complex production processes and has definitely been a challenge for this particular supplier. When we subject our suppliers to fluctuating demand forecasts it is not as easy to take notice in demand increases and suppliers might not adjust their production capacity accordingly until it’s already too late.

Although this data doesn't give us definite proof that our demand leveling experiment was a success it acts as a stimulant. Our forecasting data doesn't extend to time before the experiment but by observing the two different table (33 model production forecast vs. actual produced quantities and Crankshaft delivery schedules during weeks 11 to 20) I can comfortable state that it has made a difference. In case we need to make a decision to whether balance our forecasts or let it fluctuate, there's not much of a debate.

With more balanced forecasting we don't predispose ourselves to constant firefighting and we can focus on monitoring that our suppliers have the proper capacity to meet our needs.

8.2 Strategic inventory positioning

We established that in our environment production balancing is preferable, so where should we level our demand and where should we place our inventory? Where does inventory bring us the most "value"? Inventory is the key when it comes to reducing the bullwhip effect and it allows us to be more flexible in service to our customers, but where should we place the inventory in our supply chain and how much inventory we should have.

In chapter 4. We studied the effect of finished goods inventory would have into our demand variation with 12 different engine models and learned that it should reduce our demand variation by approximately 32% and with these 12 different models we would be able to balance production plan for more than half of the produced engines.

There's not that much risks involved with the creation of finished good buffer stock for high runner products, since the sales of such engines is rather constant and very stable, but of course when components for these engines are already used, they aren't available for other engines. Total inventory value for AGCO Power was estimated to remain somewhat the same, higher finished good inventory would in return reduce our component inventory.

In this study we were more focused on creating the finished good inventory buffer, because we assumed that our production and production planning would benefit from a more balanced production plan or production leveling, but after we consulted some of our production engineers and managers it become clear that the assumption wasn't as correct as we had first thought. High mix production wasn't seen as such an advantage, but rather a challenge. Our production felt that it was more difficult for assemblers to constantly adopt to change in assembly work configuration, instead of assembling the same engine models for a period of time and then changing to another. Balancing the production of our high runner products of course doesn't necessarily mean that we should create a higher production mix compared to what it is today and in my opinion it would enable our production to better maintain the ideal mix, since we would be able produce the same amount of high runner products every day. Nonetheless it is clear that we must investigate the effects of production leveling or heijunka (Japanese original term) further and estimate what would be the best suitable inventory positioning strategy with deeper understanding of our production requirements. Demand leveling can be done separately in a forecast level even though production doesn't follow the same plan as was the outcome with our 3.3 liter engine study, but for us to be more successful we must take into account our operations as a whole and not fall into the trap of optimizing one function without knowing what effect does it have for another.

8.3 Inventory value

Let's put strategic inventory positioning aside for a moment and look at our current operating model, where our inventory lies currently and how do we know when to replenish it and in which quantity.

AGCO Powers production works mainly with a make to order type of strategy for producing engines. Production schedule is compiled from actual sales orders and this enables our production to fulfill customer requirements with the exact product specifications such as engine software. This type of production strategy can be described as a pull – based strategy since demand for production is actual not forecasted. Component replenishment strategy on the other hand works mainly with push – based strategy since purchase orders are released before the actual customer orders are received. Component purchase orders are based on forecasted demand of our production and the accuracy of our forecast is what dictates if we have the right amount of components in our warehouse.

We learned that our forecasts are subjected to fluctuating demand, which means that our purchase orders must do the same. In case purchase schedules can't be aligned to these demand changes, we must have sufficient amount of inventory to cover the fluctuations.

In order to do that we created an inventory calculation model that considered (among other factors) the effect of fluctuating demand and determined the adequate amount of inventory required for each part. Our overall component inventory target reflected very closely the actual inventory as you can see from the chart below.

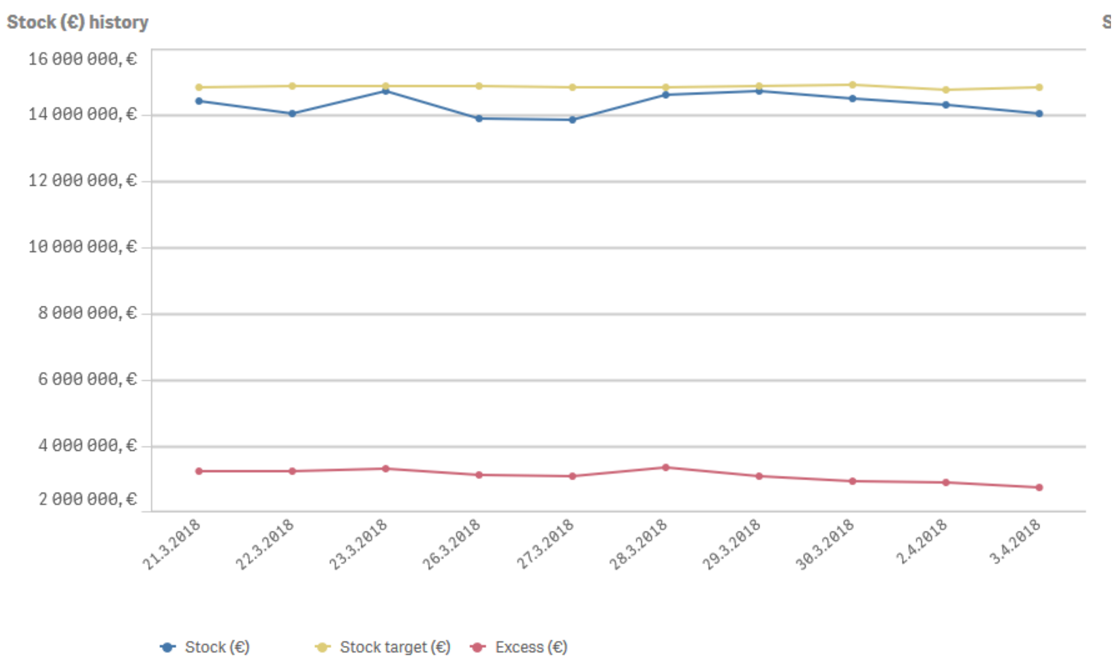

Figure 28: Actual stock compared to planned stock (AGCO Power 21.3.2018 – 3.4.2018).

Planned inventory target doesn't play a role in our purchasing process at the moment and the inventory sizing is currently based on each purchaser's intuition on how much inventory is actually required. As we look closely the two figures, stock target (yellow line) and stock (blue line) we can see that the actual stock value is a bit lower than the planned inventory value, but due to increasing demand in many business sectors including ours, our suppliers are struggling to supply our needs and these supply issues are the reason why planned inventory is lower than actual inventory.

The fact that our calculated planned inventory follows very closely the actual inventory gives us some certainty that the calculation created is trustworthy. When we dig deeper into the inventory target figures we start to see differences with planned - and actual inventory. Differences occur in component level and the calculation suggest higher inventory levels for components with higher demand fluctuations and lower inventories for components that have more stable demand patterns. Of course suppliers ability deliver parts on time (delivery accuracy) is to be considered when evaluating the correct amount of inventory, but overall I would suggest that the created inventory calculation model works as planned and it gives us the much needed guidance on the required inventory levels and visibility into our demand patterns.

Although at the moment our purchasing order processing consist of mainly manual work and requires high workload in the future we will move on to more automatic order creation – process (August, 2018) and with more automatic order processing our inventory calculation model becomes vital when controlling the process.

AGCO Power will launch a new ERP system during the year 2018 and after the implementation purchase orders or delivery schedules aren’t created manually but automatically and within this new ERP system and IT – tool it is essentially important on how we manage the process parameters. This is where our created PFEP – tool and inventory targets come in place.

8.4 PFEP – tool

One of the most valuable outcomes of this work was the creation of our materials management – tool called “Plan for every part”. Most case studies incorporate plan for every part – tools mainly to material handling activities within the company, but in our case we decided to take the tool one step further and decided to combine inventory planning as part of the tool. It was natural to combine all material management optimizing tools into one centrally managed entirety. Material handling solutions have an effect on material planning strategy and vice versa. Inventory targets visualization was the first step of the tool as we learned from the chapter 7.2 Plan for every part, but not the last. Tool has been developed to optimize all material planning processes currently in use. It doesn't just give us inventory targets and visualize them but it also monitors our planning parameters and aligns them with forecasted demand.

We started to control and optimize our supplier Kanban – process in the end of 2016 with a BI report and in the beginning 2018 the same report was included as part of our PFEP – tool. When we react to increasing or decreasing demand proactively rather than reactively, we are able to prevent possible problems before they become actual problems. That's what we have already achieved with supplier Kanban – process and in return have experienced much less shortages or near shortages and I believe the same can be achieved with each and every material management process.

8.4.1 Supplier kanban

Supplier kanban – supply strategy is one of the replenishment processes we use in material planning department and it's been in use for many years in our company. It's one of the lean manufacturing tools that use pull system to signal suppliers to deliver parts. In our case we use component packaging in addition to signal cards (Kanban cards) to indicate that more parts are needed. This particular supply strategy is mainly used for small components with stable demand, but in some cases it is also used for small components for which the correct stock count is difficult to maintain. Balance errors are mostly affiliated to incorrect BOM structures or material receival errors but in our case balance errors can also occur when parts are scrapped due to quality defects but not reported properly.

When the replenishment signal is created visually rather than systemically from stock balance, balance errors in our stock count don't affect negatively into our inventory. When a container or pallet is consumed we order more parts. This would be an ideal supply strategy if our production output would always remain the same and we wouldn't have any demand fluctuations, only balanced demand. In our case and I would dare to say that in most manufacturing organizations these two terms aren't met and since running out of components is always the worst possible outcome of our material replenishment processes, we need to plan the process according to worst possible scenario and it creates waste inside the system.

Waste or no waste inside the process we must take into account that in this process as with every process, we must control the changing variables. Supplier Kanban – process is designed with certain variables (lead time and demand) and whenever there's a change in these two variables we must adjust our process accordingly. In case our demand increases and our supplier's response time or our stock isn't adequate, we have a risk of running out of parts. Also if our demand fluctuates more radically than before and we don't have enough parts in stock, we have a risk of running out of parts. We could also end up having obsolete stock in case we order parts according to previous consumption but our demand is phasing out.

Our plan for every part – tool is designed to control the supplier Kanban - process and react to changes in demand. It monitors our process according to the latest demand information and notifies material planners in case change is required into our planning parameters. For example in case we need to increase or decrease stock. In most cases our supply lead times aren't so short that these pull systems can keep up with demand increases and we need to align our process according to new demand information, this can be achieved by increasing the part quantity in stock and by making sure our supplier does the same (in case lead times are relying on supplier stock).

8.4.2 Next development phases of PFEP – tool

As previously stated the goal is to control and optimize every material management process with the same tool and we have set an implementation plan that consist of seven steps.

1. Management KPI's (Overall inventory target vs. actual inventory and excess inventory, future inventory development, Days on hand inventory).
2. Material planning (Safety stock and safety time parameter changes, Excess and Inadequate inventory, Future development of inventory according to current delivery plan).
3. Material reception (Optimal warehouse location according to demand category (ABC), Optimal replenishment method to production line).
4. Line feeding (Optimal Kanban container quantity and size, Miniload warehouse min/max – parameters).
5. Stock count (Obsolite materials)

6. Logistics costs (Working capital, warehousing, handling, packing and transporting).

We have already finished the first two steps of the implementation plan and the next steps are planned to be finished at the end of Q1, 2019.

Figure 29: PFEP - tool development and implementation plan.

8.5 Conclusions

We concluded that our master production schedule (long-term schedule) consist of mainly direct customer forecast (12 months) and we don’t really need to predict the demand for our products, but the challenge is demand variability and because of that operative purchasing is having trouble maintaining stable forecasts in terms of material purchases. We either have too much materials or too little for our production needs. Demand changes can’t be characterized solely to causal but rather to constant variability.

For example today our customer might forecast a need of 30 engines for a specific week but next week demand might be reduced to 15 engines and in two weeks the need is again 30 engines, for the same week in question.

Our ERP and MRP directs our material purchases from dependent demand of our products, but if we continue allowing MRP to run in an environment where we experience high demand variability our stocks will have to remain high.

To reduce variability we must improve co-operation with our customers. Strategic partnerships should be also aligned in operational level. This would allow us to gain insight into our customers production planning and we would be able share our challenges.

One strategy to manage demand variability is postponement, where the end product is constructed at the latest possible stage according to specific customer configuration. Main production is separated from the customer configuration stage and a very generic model is produced in the main production line. This strategy of course doesn't benefit our production as much if the final configuration is set at very early stage of the production and as we discovered was the case with our oil sumps.

JIT concept is also extremely difficult to establish since most of our suppliers are located in Central or Eastern Europe and transportation times are long. In case our sourcing strategy would be to localize supply of components that cause our product proliferation, we could call-off those components with just in time – or just in sequence methods. In order for this strategy to successful our suppliers shouldn't have long material lead times with many material variants. In the oil sump case, there are excellent local machinist but not so many casting suppliers and if we have as many castings as we have oil sumps, localizing oil sumps doesn't remove the problem of demand variability, it only transfers it to our supplier. On the other hand there might be many other components for which localizing supply would be the best possible solution, but in order to discover those components we need to better study our component structures and demand patterns.

Forecast inaccuracy should be also examined with our products and we should analyze what is the actual demand variability in our master production schedule in order to address the problem clearly. We only need to discover the products where our forecast inaccuracy is the highest and study reasons behind that in more detail. Each MPS is saved into company database we just need to create a way to analyze them and if we have the sufficient data to study, it's much easier to derive the cause. We could combine the MPS data and see how much planned demand variates within each production week and in which time period. Period of first two months is most critical so this is where we need to focus our analysis. With better knowledge of our forecast inaccuracy and demand patterns we know where production balancing would be most beneficial for purchasing and our suppliers.

Supply chain is only as strong as its weakest link and as we optimize or redesign our processes we must know what effect it has on our supply chain as a whole.

With material management tools such as plan for every part we are able to align and control our processes to reflect changing conditions in our supply chain.

In case AGCO Power aims to further develop production balancing, our inventory targets should reflect that development and that is the interconnectivity our inventory management sorely required. As a result of this work we managed to set minimum - and maximum stock targets for our materials but since we don’t know the actual forecast inaccuracy they are oversized and assume that each product has as high inaccuracy as is the current demand variation for each product and in order to improve our stock targets to better reflect the reality, we must also analyze forecast inaccuracy.

With the work encapsulated in this thesis we managed to create a basis for managing our supply chain. We pointed out the current situation and the challenges our supply chain management faces today and created strategies and proposals on how to better manage these challenges, but most importantly we created a tool that aids to plan and control our processes according to our current situation, challenges included.

We are only beginning to understand our demand patterns and the effects they induce into our SCM. With better understanding and data analytics we are able to improve our processes simultaneously and that is the road we have to embark upon.

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Appendices

Appendix 1. Interview questions for order management employees.

Henkilöhaastattelut: Logistiikan toimihenkilöt
Viitekehys: Kysynnän ja toimitusten variaatio. Millainen vaikutus variaatiolla on työn sisältöön ja sen tuloksiin'
Kysymykset:

1 . Muutokset:	Kuinka suurena haasteena arvioisit muutokset asiakas kysynnässä nykyisessä toimessasi?	Kuinka suurena haasteena arvioisit muutokset toimittajien toimitusten oikea-aikaisuudessa nykyisessä toimessasi?	Koetko muutokset asiakaskysynnässä vai toimitusten oikea-aikaisuudessa haasteellisempana?
A	Erittäin haastavana	Erittäin haastavana	Molemmat ovat yhtä haastavia
B	Jokseenkin haastavana	Jokseenkin haastavana	Asiakaskysyntä selvästi
C	Vähäinen vaikutus	Vähäinen vaikutus	Asiakaskysyntä jokseenkin
D	En koe haasteena	En koe haasteena	Toimitukset selvästi
E			Toimitukset jokseenkin
Millaista kehitystä toivoisit nykyisiin toimintatapoihin edellä mainittujen haasteiden kohdalla?			
2. Muutoksiin reagointi	Kuinka arvioisit mahdollisuuksiasi toteuttaa syntyneet asiakaskysynnän tai toimituspäivien muutokset?	Kuinka työllistävä vaikutus arvioisit asiakkaiden kysynnän muutoksilla olevan päivittäiseen työhösi?	Kuinka työllistävä vaikutus arvioisit toimituspäivien muutoksilla olevan päivittäiseen työhösi?
A	Kaikki	yli 80% ajasta	yli 80% ajasta
B	Lähes kaikki	yli 50% ajasta	yli 50% ajasta
C	Puolet	alle 50% ajasta	alle 50% ajasta
D	Vähemmän kuin puolet	alle 20% ajasta	alle 20% ajasta
Kuinka suuresti arvioisit seuraavien asioiden työllistävän sinua tällä hetkellä työssäsi? 1. Muutokset ennusteessa lähitulevaisuudessa 2. Muutokset ennusteessa kaempana tulevaisuudessa 3. Toimittajat eivät vahvista toimituksiaan 4. Toimittajat pyytävät jatkuvasti muuttamaan toimitusohjelmaa 5. Toimitukset eivät saavu ajallaan			
3. Tulostavoitteet	Ovatko nykyiset tulostavoitteesi varastosta saavutettavissa?	Heijastavatko nykyiset tulostavoitteesi varastosta todellista työnhaasteellisuutta?	
A	Kyllä, helposti	Kyllä, hyvin	
B	Kyllä, juuri ja juuri	Kyllä, osittain	
C	Ei, melkein	Ei, melkein	
D	Ei, kaukana siitä	Ei, kaukana siitä	
Mikä seuraavista asioista vaikuttaa mielestäsi eniten varastotavoitteiden toteutumiseen? 1. Muutokset kysynnässä 2. Toimitusvarmuus 3. Pitkät toimitusajat 4. Informaation kulku			

Appendix 2. Interview questions for supply chain managers.

Henkilöhaastattelut: Logistiikan johtajat

Viitekehys: Kysynnän ja toimitusten variaatio. Millainen vaikutus variaatiolla on työn sisältöön ja sen tuloksiin.

Kysymykset:

1. Muutokset:	Kuinka suurena haasteena arvioisit muutokset asiakas kysynnässä nykyisessä toimessasi?	Kuinka suurena haasteena arvioisit muutokset toimittajien toimitusten oikea-aikaisuudessa nykyisessä toimessasi?	Koetko muutokset asiakaskysynnässä vai toimitusten oikea-aikaisuudessa haasteellisempana?
A	Erittäin haastavana	Erittäin haastavana	Molemmat ovat yhtä haastavia
B	Jokseenkin haastavana	Jokseenkin haastavana	Asiakaskysyntä selvästi
C	Vähäinen vaikutus	Vähäinen vaikutus	Asiakaskysyntä jokseenkin
D	En koe haasteena	En koe haasteena	Toimitukset selvästi
E			Toimitukset jokseenkin
Millaista kehitystä toivoisit nykyisiin toimintatapoihin edellä mainittujen haasteiden kohdalla?			
2. Toiminnan kehitys	Kuinka arvioisit mahdollisuuksiasi toteuttaa syntyneet asiakaskysynnän tai toimituspäivien muutokset? Mikä on vastuualueesi palvelukyky	Miten järjestäisit seuraavat asiat tärkeysjärjestykseen kehittämisen kannalta (mikä alue vaatii eniten huomiota)?	Millaisen painoarvon antaisit edellämainittujen asioiden kehittämiselle? (%)
A	Kaikki	Toimitusvarmuus	0-100%
B	Lähes kaikki	Kustannukset	0-100%
C	Puolet	Työn sisältämä hukka	0-100%
D	Vähemmän kuin puolet	Toimittajien joustavuus	0-100%
Millaisiin työtehtäviin tulisi alaisesi tulevaisuudessa kiinnittää enemmän huomiota ja millaisiin työtehtäviin vähemmän huomiota?			
3. Tulostavoitteet	Ovatko nykyiset tulostavoitteesi varastosta saavutettavissa?	Heijastavatko nykyiset tulostavoitteesi varastosta todellista toimitusketjun tilannetta?	Kuinka suuri tulisi varastonkierron ja palvelukyvyn olla 5 vuoden kuluttua?
A	Kyllä, helposti	Kyllä, hyvin	
B	Kyllä, juuri ja juuri	Kyllä, osittain	
C	Ei, melkein	Ei, melkein	
D	Ei, kaukana siitä	Ei, kaukana siitä	
Mikä seuraavista asioista vaikuttaa mielestäsi eniten varastotavoitteiden toteutumiseen? 1. Muutokset kysynnässä 2. Toimitusvarmuus 3. Pitkät toimitusajat 4. Informaation kulku			