Lean supply chain control in Hydro Automotive Structures

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Abstract: This paper presents the ongoing process and experiences from the development and implementation of the "Every Product Every…" (EPE) principle in supply chain control at Hydro Automotive Structures Raufoss (HARA). The principle is based on the idea of implementing cyclic plans as a means to level production, improve efficiency and to gradually reduce batch sizes and move towards the Lean ideal of one-piece flow. The purpose of the paper is to provide an illustrative case, describing the process and challenges in developing lean supply chain control.

Keywords: Lean manufacturing, supply chain, batch production, every product every

INTRODUCTION

Hydro Automotive Structures Raufoss (HARA) supplies the automotive industry with crash management systems as well as develops and manufactures bumper beams for almost all major original equipment manufacturers (OEM). HARA is a part of the Hydro group. Hydro is a Fortune Global 500 supplier of aluminium and aluminium products. Based in Norway, the company employs 22,000 people in more than 30 countries and is represented on all continents. One of Hydro`s business areas is the automotive industry within crash management. Crash management (front/rear) is one of the major applications for aluminium extrusions in the automotive industry, and plants dedicated to crash management are located in Raufoss (Norway), Louviers (France), Skultuna (Sweden) and Holland (MI, US) (Hydro, 2008). The supply chain from billet casting, through extrusion of profiles to forming and some machining operations are all situated in Raufoss. From Raufoss the bumpers are sent directly to the OEM, the assembly plants or third party logistics providers, before it's sent to the OEM. One of Hydro Automotive Structures main improvement initiatives has been the implementation of Lean philosophy and practices. This work has lead to the development of the Hydro Automotive Production system (HAPS), an improvement programme, which describes their philosophy and steps to grow towards Manufacturing Excellence. HAPS is based on the principles of Lean Manufacturing and the Toyota Production System.

HARA have in the last few years experienced how demand fluctuations have caused rush orders in the supply chain, complicating supply chain coordination. The effect in each plant has been unpredictable plans, high work in progress inventory, difficult capacity and resource planning. To improve performance, HARA have decided to move from the existing Material Requirement Planning (MRP) to the adaptation of the Every Product Every principle for manufacturing planning and control. The principle is based on the idea of implementing cyclic plans as a means to level production, improve efficiency and to gradually reduce batch sizes and move towards the ideal described in Lean as a one-piece flow. This paper will describe the development and implementation process of the EPE principle at in the supply chain.

The research method is based on action research. Action research is the practice of both studying and analyzing a phenomenon while at the same time participating in development and improvements (Greenwood and Levin, 1998). The work was carried out in the national research project “CRASH – integrated, differentiated and lean supply chain for aluminium products to the automotive industry” (2006-09). The focus of the research presented in this paper, has been lean supply chain production planning and control. Together, the researchers and the project participants defined the control challenges and worked together to solve them. The research process was carried out through a series of workshops to analyse the existing planning and control system, and to develop and implement the EPE principle for supply chain control.

The paper is organised as follows. First we describe the supply chain planning and production processes at HARA with a summary of the identified challenges. Thereafter the theoretical background and the effects of EPE are presented. The final section of the paper describes the implementation process of EPE in one plant and presents a solution for introducing EPE in the supply chain.

TODAYS SUPPLY CHAIN CONTROL

The supply chain at Raufoss is described in Figure 1 and includes a simplified material and information flow from the suppliers of ingot and alloy to the end customer.

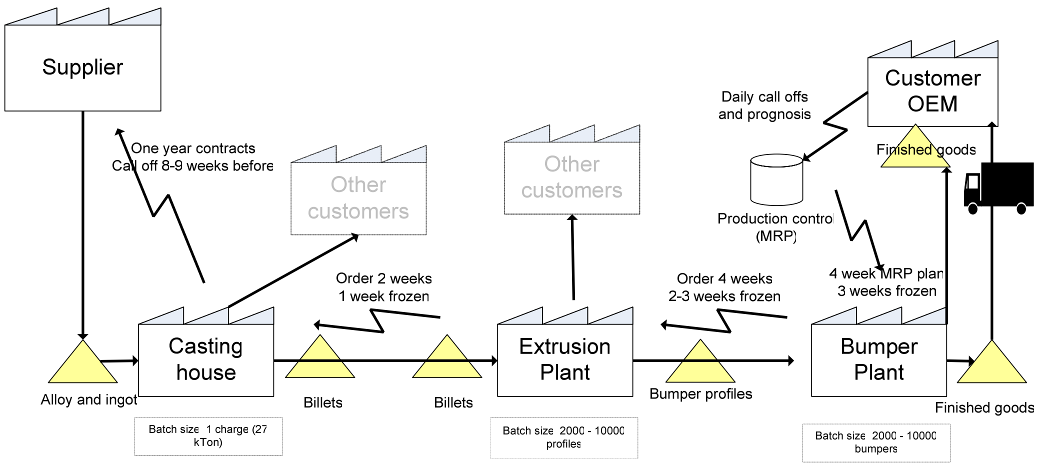

Figure 1 Today`s supply chain control.

The supply chain at Raufoss is a traditional supply chain with order based supply chain control. MRP calculations (based on customer call offs and forecasts) is the basis for a 4 week rolling production plan with a three week frozen period at the bumper plant. These plans are communicated to the extrusion plant which daily schedules production, based on a developed plan with a two-three week horizon. The extrusion plant develops orders with a one week frozen horizon and a forecast for the following week that is sent to the next tier, the casting house. In the casting house, production plans are made according to defined inventory levels and the orders from the extrusion plant. Products to other customers are made to order. The planning function in the supply chain has been traditionally organised with separate planning functions, and orders have been placed to the next tier according to demand and plans. Orders and plans have been communicated through email and telephone. Coordination meetings between planners have taken place, but with irregular frequency. Different operational priorities in the supply chain, has lead to sub-optimisation with little synchronisation of processes across the supply chain. The result is a supply chain that is characterised by long lead times and high inventories.

Challenges in today's supply chain control

A major challenge for the supply chain has been its response to fluctuations in OEM demand. A typical scenario is when changes in OEM orders lead to new MRP calculations and subsequent changes in production plans for the bumper plant. This has led to rush orders throughout the supply chain. The effect in each plant has been unpredictable plans, high work in progress inventory, difficult capacity and resource planning. As a result of this, the supply chain was not synchronised, but producing products at different takt and in some cases producing the wrong product and creating unnecessary inventory, i.e. not showing the characteristics of a Lean supply chain as described in the next section. Fire-fighting has been the norm (for both operators and planners) and less time has been devoted to continuous improvement on the shop-floor. To further complicate the situation each plant, with its different processes, has had different strategies to achieve high productivity (e.g. large batches). Discussions regarding economic batch quantities and batch size coordination have taken place, but with few concrete results. Information exchange in the supply chain can also be characterised as traditional as only the bumper plant have access and use end customer demand in their planning. Extrusion plant and casting house receive market information only through orders in the supply chain, and planning is carried out at each plant. In sum the situation could be described in the following points:

1. Change in customers orders caused frequent plan changes and rush orders in the supply chain, thus complicating supply chain coordination
2. Focus on high resource utilisation in each plant and no coordination in batch sizes between plants, resulting in large batch sizes and subsequent high inventories
3. Traditional information exchange, with limited information transparency (only bumper plant can see customer demand) and lack of collaborative planning processes.

To meet the described challenges HARA carried out a set of workshops and training to come up with possible manufacturing planning and control principles to improve material flow. The variability of demand was identified as a key challenge and actions to counter this was prioritised. The goal was to achieve a levelled production throughout the supply chain, where production was shielded from customers demand fluctuations. The following section describes the theoretical background for the development of the Every Product Every principle to achieve level production in the supply chain.

DEVELOPING THE EVERY PRODUCT EVERY PRINCIPLE

A true lean supply is characterised by a smooth flow of material, short lead times, and very little inventory. All actors in the supply chain are aware of the rate of customer consumption, i.e. the takt time, and produce accordingly (Jones and Womack, 2002). Then only the necessary products are manufactured, at the necessary time, in the necessary quantity, and in addition the stock on hand is kept to a minimum (Sugimori, et al. 1977), i.e. Just-in-Time production. A complication factor in achieving this flow of products is the fluctuation in demand. The case in most companies is that the quantity withdrawn by the subsequent process varies considerably. As a result the processes within the company as well as subcontractors will maintain peak capacity or holding excessive inventory at all times. At Toyota and other car manufactures this has lead to a levelled production schedule where the production sequence is carefully planned with regards to cycle times and material requirements. This has helped them achieve the final goal of one-piece flow matched to market pull through takt time.

The concept of one-piece flow is considered difficult in batch production due to their production system capacities, where resource utilisation is key and large batches is the answer (Glenday, 2004). Traditionally these companies use MRP systems in calculating plans, focussing on efficiency and economies of scale considerations. When changes in demand and production breakdown occur, the plans are continuously changed while fire-fighting and chaos becomes the norm (Mitchell, 2006). These challenges were also encountered in HARA, as all the three companies are traditional batch producers, which try to achieve high equipment utilisation and few changeovers.

To overcome this challenge and make just-in-time production possible in batch production, one approach is to develop a level production schedule. Glenday (2004) proposes that levelled batch production is possible through the implementation of a fixed production schedule that is rigidly followed. This means making the same products, in the same sequence, in the same volume, on the same equipment, at the same time, with the same sequence, every cycle.

Introduction of a cyclic plan, based on customer demand, will create a takt within one plant in the supply chain. The next step is then to synchronise the whole supply chain with a takt that is aligned to customer demand. This is however a challenging task due to the different operational strategies we often find between companies in a supply chain. Realising such a lean supply chain requires a tight relationship with suppliers and customers, and for each manager to focus on the performance of the entire supply chain (Womack and Jones, 1994).

The EPE principle

The EPE principle is based on cyclic planning, and introduces a fixed production plan to increase plan predictability and to then gradually reduce batch sizes towards one-piece flow.

When developing these fixed cycles/cyclic plans, there are a number of considerations related to production and inventory, e.g. batch sizing, assignment to machines and sequencing of products (Ashayeri et al., 2006). Glenday (2004) propose to start with a classification of products based on volume (ABC–classification) and presents a possible scenario. Similar classifications were done at HARA.

Cumulative % of Volume	**Cumulative % of SKU`s**	**Color code**	**Control principle**
50 %	6 %	Green	Fixed production cycle
95 %	50 %	Yellow	Attempt to include in cycle with green products
99 %	70 %	Blue	
Last 1 %	30 %	Red	Are these products profitable? Produced on dedicated machines or in specific slots.

Table 1 Product classification for cycle development (Glenday, 2004).

This classification is a good starting point for a differentiated control of the products based on volume. High-volume products (in this case only 6 %) can be produced in a fixed product cycle every week (EPE-principle) and create a ”green stream” of products through the factory with short lead times and continuous flow. These products can be produced every week as demand is high and stable. This green stream is the main flow in production and establishes a rhythm for operators and support functions.

The yellow and blue products are more difficult to introduce in a fixed cycle as their demand is less stable. Dependent on demand and changeover time these products can be introduced in a fixed cycle, but with lower frequencies e.g. every second or third week. There can also be fixed slots in the production plan for these products, and where they will be produced if there is demand. For the red products it should be carefully investigated whether these products are profitable considering the administrative and production cost that incur from making these products. If they are strategically important, they can be produced in separate slots or on dedicated machines.

A prerequisite for EPE is a finished goods inventory buffer that absorbs fluctuations in demand. This does initially increase inventory, but is essential in creating stability on the shop floor as well as a stable collaboration environment in order to synchronise production in the supply chain. With this stability in place, focus will be on reducing changeover times to be able to reduce batch sizes, resulting in reduced inventory. Another prerequisite is that the plan is executed according to the planned sequence and volumes, to create the desired predictability for the supporting functions.

Effects of EPE

Initially EPE results in more stable plans and a set rhythm on the shop floor. As this fixed cycle schedule is repeated, “economies of repetition” will start to emerge (Glenday, 2004). Routines can be established, so that work can be standardised and continuous improvement processes initiated. In batch production changeovers are especially targeted and will be improved. This improvement in capability and capacity will allow more products to be included into a fixed sequence, enabling the cycles to be more frequent, shorter and more flexible in order to progressively match volumes to actual market demands. The final result of this process will be a one-piece flow of products to meet customer demand.

Cyclic planning literature provides several examples of how cyclic planning principles have improved performance in single companies. Mitchell (2006) refers to companies like 3M, Wrigley and Kimberly-Clark where levelled production planning have resulted in increased throughput up to 30 %, reduced changeovers by 50 % and reduced wreck with up to 50 %. Schmidt et al. (2001) provides an illustrative case description where Alcoa implemented cyclic planning to manage capacity, increasing output by 20 %. For Alcoa the improvement in planning and production and maintenance planning contributed to improvements in; die changes, work-in-process inventory, machine maintenance, workforce planning and customer service. The plan was also the foundation for better coordination and planning of all related activities (Schmidt et al., 2001).

Van Den Broecke et al. (2005) describes the benefits of common repetitive production plans in a supply chain. The predictability of the schedule allows synchronisation between the different production stages. In situations where capacity on selected resources is limited, a cyclic production schedule which distributes loads evenly on the operations will reduce the possibility of peak demands arriving all at once and claiming the use of the capacity constrained resource.

IMPLEMENTING EPE AT HARA

Based on several workshops and HAPS material, management introduced the Every Product Every principle, as the main manufacturing planning and control principle for the supply chain. To ensure a good implementation, a four step process was developed in implementing EPE in the bumper plant. The implementation has started in the bumper plant in one of the forming lines, in order to harvest experience and evaluate the principle.

The process was made up of these steps.

1. Value stream mapping
   Based on an ABC- classification of products, the major value streams were identified and mapped by the operators. Results from the value stream mapping e.g. lead times, changeover times and volumes were important input when developing the plan.

2. Capacity and bottleneck analysis
   Product volumes and production capacities were analysed to identify bottlenecks. This resulted in an aggregated production plan that allocated products to press lines in order to balance capacity in the plant.

3. Development of plan
   A simple level production planning method was developed. The resulting plan was based on MRP calculations and fixed for four weeks. Line capacity planning (batch sizes and sequences) was carried out based on the levelled demand, within the four week time horizon. Maintenance operations and spare part was also included in the plan. Analysis of economic batch quantities, in both bumper lines and the extrusion plant, were carried out. These results provided important answers and guidelines in the development of the plans and batch size determination.

4. Implementing and follow up of plan

> In order to realise the benefits of EPE, it is crucial that the plan is executed according to the planned sequence and volumes, to create the desired predictability for the supporting functions. Key performance indicators were therefore introduced to follow up planning adherence, i.e. if the products were produced in the correct frequency and in the planned volume.

One of the bumper lines is today running an EPE plan where all products are produced with a given cycle frequency and volume. The effects have been fewer peaks in production and easier management of supporting activities.

THE EPE SOLUTION IN THE HARA SUPPLY CHAIN

Realising the benefits of EPE in the supply chain requires that the development of a plan that is adapted to the companies' different processes and that synchronises material flow in the supply chain. Developing such a plan is a challenging task since each company has different processes and operational strategies to optimise their performance. A production cycle established at one bumper line might be optimal for this line, but sub-optimal considering the whole supply chain.

Through a workshop all the different factors that are taken into consideration in today's production planning at each plant were identified. A number of these factors were common for all the three companies. These were:

- Balancing number of shifts
- Utilise and balance production capacity
- Batch size
- Product sequence
- Tool availability
- Deliveries to several customers
- Available inventory space

Even though the factors were common they will naturally result in different operational priorities since they all relate to different production systems and processes. An example can be illustrated through the balancing of shifts. The three companies vary between using 3, 4 and 5-shift in production. It's desired to have as few changes between numbers of shifts as possible. Balancing of shifts between the three companies is difficult since the casting house and the extrusion plant also have other customers. The result can therefore be that inventory increases in periods or in other periods that deliveries are missed, because of a mismatch between number of shifts and the demand in the supply chain.

Models for developing cyclic plans

There are several examples in literature of cyclic planning and synchronisation of production processes both in a single plant and in a multi stage supply chain (see for example Van Den Broecke et al. (2005)). These examples deal with assignment of product to machines, lot sizing and sequencing of products. Many examples are complicated with several hundred products with different process routes, and require the development of mathematical models to solve them (see McGee and Pyke (1996)). The advantages of such models are that they can handle a large amount of data and provide

the user with an “optimal” solution. Developing such models are however time consuming and require expert knowledge and provide solutions based on a number of simplifications from the real situation.
Silver et al. (1998) provide a number of different models when, deciding the optimal lot sizes, considering set up and inventory cost. Different rules can be applied in determining the cycles. One of the simplest rules is the case when the cycle time of any stage is an integer multiple the cycle time in the following operation. The process closest to the customer will set the base planning cycle that will determine possible cycles in the upstream processes. McGee and Pyke (1996) present an algorithm using powers-of-two multiples of the base period in cyclic planning. Power of two multiples created a greater sense of order, allowing regular preventive maintenance, communication with non-automotive customers about production schedules, and easier scheduling of operators (McGee and Pyke, 1996).

The proposed EPE solution at HARA

To establish a good plan for the supply chain at Raufoss, several analyses were carried out considering processes and batch sizes at both the bumper, extrusion and the casting house. The bumper plant is closest to the customer and has traditionally set the terms for the rest of the supply chain through their production plan and corresponding orders. With varying changeover times between the different lines, certain restrictions must be made to the lot sizes in the bumper lines. The extrusion process is the most flexible in the supply chain with short changeover times, but to ensure high productivity (kg/hr) each tool must be used to its full capacity. In the casting process, lead times are long and full batches must be made to utilise capacity and ensure high productivity.

Based on these considerations it seems reasonable to establish optimal cycles for the bumper plant, and let these also be the cycles for the extrusion plant. The two plants will produce at the same takt, with the extrusion plant producing the profiles some days before they are required in the bumper plant. Lot sizes should however be coordinated to ensure good utilisation of the tools. The principal solution is illustrated in Figure 2.

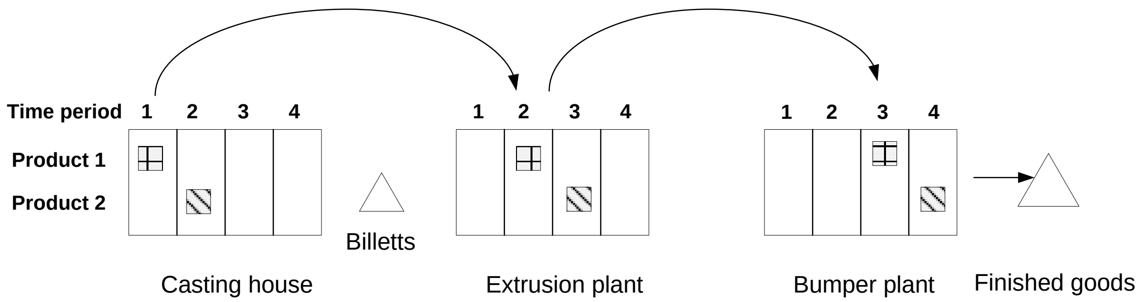

Figure 2 Principal EPE solution in the HARA supply chain.

Due to long lead times and large batch sizes in the casting house, these products will be produced to stock as shown in Figure 2. The amount that should be kept in stock could be calculated from the cycle that will be introduced in the extrusion plant.

Lot-size considerations and assignment issues are relatively simple in the HARA case, but sequencing requires more attention. When each bumper line establishes a cycle, this will be accumulated to a cycle for the extrusion plant and can cause capacity problems.

With a number of considerations shown earlier, there is a need for a through analysis of how different cycles will affect the production pattern in the extrusion plant and if this is feasible. Such analysis often requires mathematical models.

SUMMARY

This paper presents the preliminary results from the research project CRASH that aims to develop lean supply chains in the automotive industry. The paper describes the ongoing process and development of the Every Product Every principle for manufacturing planning and control in the supply chain at Hydro Automotive Structures. The EPE principle is based on cyclic planning, and introduces a fixed production plan to increase plan predictability and to then gradually reduce batch sizes towards one-piece flow. Effects of EPE are a result of the predictability that is established through cyclic plans, e.g. easier to coordinate other processes with the plan, reduced changeover times and increased throughput.

Establishing cycles in each plant and in the supply chain must take into account assignment of product to machines, lot sizing and sequencing of products. In addition there are other individual factors in each plant such as capacity, utilisation of personnel and equipment that must be taken into account. In the EPE solution for the HARA supply chain, the bumper plant determine the cycles for the supply chain, and the extrusion plant follow the same cycle. Due to long lead times and large batch sizes in the casting house, these products will be produced to stock.

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