The fit of planning methods for the part manufacturing industry, a case study

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Abstract This paper investigates the specific planning environment of an automotive part manufacturer and characterizes this environment based on variables regarding the product, its demand and the manufacturing process. The fit of different planning methods, namely material requirements planning, reorder point, cyclic planning, kanban, and heijunka to this specific planning environment is analyzed and evaluated by exploratory research. The results show that different product characteristics make it hard to apply a single planning method. None of the investigated methods show the ability to cover the complex requirements of a combined planning environment of two partly divergent product types with a deep value chain.

Keywords Production planning environment · Production planning methods · Automotive part manufacturing

1 Introduction

Achieving a high manufacturing performance requires the application of specific planning methods, so that the applied planning method matches with the specific planning environment that it is applied to [1]. Different planning methods do not only have divergent requirements and

prerequisites, like the need for information and communication technology support in the case of material requirements planning, they also differ in their applicability to different planning environments. Planning environments are characterized by dimensions of product, demand and manufacturing process attributes [2–4]. Thereby the choice of a suitable planning method is highly dependent on the individual planning environment as context of application [3].

The importance of process choice for the planning environment was also outlined by Olhager and Rudberg [5]. Jonsson and Mattsson [3] developed a framework to analyze individual planning environments by specific variables. Existing studies in the literature focus either on comparing the implication of different planning methods, or on describing frameworks to differentiate planning environments. Accordingly, Jonsson and Mattsson identified a lack of matching planning environments and planning methods. Olhager and Wikner [6] stated that especially the causality between variables that characterize planning environments is of high importance. In addition, Jonsson and Mattsson [7] recommended future research to investigate which planning methods are appropriate to different planning environments. The intention of this paper is to apply the methodology of analyzing a planning environment with the framework given by Jonsson and Mattsson in the context of a specific industry example and to analyze planning methods for their suitability.

Literature review has been utilized in order to investigate existing frameworks and deployed variables for the analysis of planning environments. Further publications of the authors have been reviewed related to the inspected framework for characterizing planning environments. A framework basing on Jonsson and Mattsson was applied to the specific industry example.

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Current literature on planning and control describe several different production planning methods. Examples are: material requirements planning (MRP) and capacity resource planning (CRP), reorder point (ROP), just-in-time (JIT) and just-in-sequence (JIS), cyclic planning, kanban and heijunka, optimized production technology (OPT), theory of constraints (TOC) and drum-buffer-rope (DBR), load-oriented control (BOA) and periodic batch control (PBC), and project production control (PPC) [8–13].

Different authors investigated the application of selected planning methods. This has been done with a general scope [7] and also in relation to the planning environment [1]. In this paper we continue with this stream and apply the most cited of the mentioned planning methods to a specific planning environment. The chosen planning methods are evaluated on their suitability for this specific planning environment.

The empirical data in this study come from a large Norwegian producer of aluminium automotive parts. The authors are involved in applied research projects with the company for more than two decades. The current project includes the aim to find a new concept of production management for the internal manufacturing supply chain. The primary research method of this paper is case study research [14] following a theory building approach [15]. Data collection is based on semi-structured interviews, workshops, meetings and discussions, observations, analysis of types of company reports and further provided documents. In order to ensure the repeatability of the data collection and reliability, a case study protocol was developed and applied. Validity was ensured by data triangulation via multiple sources of information. In addition the derived practical findings were verified in several workshops.

2 Reviewing well-known methods for production planning and control

In this chapter, we briefly review a number of frequently cited methods for production planning and control. We introduce MRP, ROP, and kanban, which have previously been selected by various authors to investigate support of planning methods for different production environments [1, 2, 5, 6, 16]. In addition, the planning methods of cyclic planning and heijunka have been selected for further investigation. These methods have had considerable success as lean methods for production planning and control, which makes them particularly relevant within the context of assessing methods for production planning and control in different manufacturing environments. Each of these methods is briefly introduced as follows.

2.1 MRP

MRP starts from forecasts or actual customer orders and determines the requirements to fulfill the needs of the master production schedule (MPS). It uses exploding, offsetting, and netting to define the required component quantities that need to be produced or purchased [5]. Fulfilling the function of order planning, MRP ensures the planning of material supply [17].

2.2 ROP

The inventory level of each item is monitored constantly and whenever it drops below the reorder point, a production order of a predetermined quantity is released to production. The reorder point is given by a defined safety stock level plus expected demand during lead time [18, 19].

2.3 Cyclic planning

Cyclic planning “coordinates production by temporary reserving process steps to products in a pre-assigned, cyclic way” [20, 21]. Cyclic planning can combine the planning on the MPS and shop-floor level, or can be used as a singled approach just for the shop-floor planning.

2.4 Heijunka

Heijunka is the method used within lean production management to level production in terms of product volumes and product mix. Synonyms are production leveling, production smoothing or level scheduling [19, 22].

2.5 Kanban

Kanban is classified as a production control system that ensures a local information flow system with communication between a buffer and the immediate upstream machine [22]. Cards are used in order to record and document the concrete demand of materials and trigger new jobs by completion of another.

3 Characterizing the planning environment of an automotive part producer

In this section, firstly, we briefly introduce the case company in general. Thereafter, its planning environment is characterized. The current planning approach is characterized and resulting challenges are highlighted.

Fig. 1 Product life cycle

3.1 The case company

The case company is a large producer of automotive aluminum parts. The company owns the entire value chain from producing the raw material until the finished product. This includes casting through extrusion to forming and finishing. Product variants multiply after each production process, from 20 variants for the casting, to 200 variants for the extrusion, up to 450 variants for the finishing.

The present paper concentrates on the forming process, which is done in highly integrated and automated forming lines with up to four form pressing steps. The company has three main lines, and each of which can produce parts for a variety of customers (car brands). This is achieved by means of product-specific tools, one for each form pressing step.

The production involves heavy machinery and product specific tools. Switching the product thus requires changing the set of tools in the line every time, which is a complex task requiring significant time, labor, and material. This results in long lead times and long changeover times. This is especially the case for the high increase of variants during the forming process. Thereby the long set-up times represent a key characteristic.

A further special issue is the lifecycle of the products. They transform from serial parts into spare parts over time. Automotive parts typically have high demand during a 5–7 years period, in which the parts are shipped to the customer's car assembly line. After this serial production phase, producers of parts are required to deliver spare parts for additional 15 years, at least. Figure 1 illustrates the

Table 1 Planning environment of the forming process at the case company

Product	Demand	Manufacturing process
BOM complexity: one level	<i>P/D</i> ratio: <1	Manufacturing mix: mixed products
Product variety: approximately 300 different variants	Volume/frequency: usually high for serial parts, low for spare parts	Shop floor layout: product layout
Degree of value added at order entry: high	Type of procurement ordering: blanket order release from delivery agreement	Batch size: large
Proportion of customer specific items: fully customer specific products	Demand characteristics: dependent	Throughput time: days
Product data accuracy: high	Demand type: customer order allocation	Number of operations: few
Level of process planning: fully designed process	Time distributed demand: time distributed Source of demand: customer order (call-off) Inventory accuracy: low	Sequencing dependency: high

product life cycle and the development of volume over time.

The spare parts phase is characterized by low volumes and irregular demand. As a consequence, each forming line needs to cope with a mix of high- and low-volume parts. Serial parts are ordered regularly in large batches up to 25,000 pieces, with relatively little variation in size. Due to the complex changeovers, spare parts are also produced in rather large batches, however much more infrequently.

3.2 The planning environment

This section takes a closer look at aspects of relevance for planning, described by the company's planning environment. For the characterization of planning environments, several studies have taken the dimension of product, demand, and manufacturing process into account [2–4]. This study uses Jonsson and Mattsson's framework as a starting point in order to characterize the company's planning environment regarding the forming process [3]. This is shown in Table 1, which will now be briefly explained.

The products themselves can be described as piece parts [23] and contain only a very flat bill of material. The product development is based on long-term manufacturing contracts. Serial parts and spare parts have some divergent

Fig. 2 Production planning approach of the case company

characteristics regarding the planning environment framework, especially related to the demand volume and frequency (see Table 1). Due to the car manufacturers offering an increasing number of variants, there is an exponential rise in product breadth for the case company in recent decades. This accordingly adds complexity to the task of analyzing the planning environment of the company. Due to the dedicated products and their manufacturing, the product data accuracy is very high. The same applies for the level of process planning, which is completely designed based on the needs of the customer's requirements towards the product.

To understand the demand pattern, the product specific lifecycle requires further explanation. In this case, contracts are made for the complete product lifecycle of each product. Therefore blanket order releases based on delivery agreements exist. While the *P/D* ratio is constantly less than 1, the demand volume changes over the lifecycle of the product (see Fig. 1).

Related to the manufacturing process, the manufacturing mix consists of large batches as well as smaller batches. The shop floor layout is product-oriented deploying automated processes. The throughput time in forming is in the order of days, while only few operations take place, which have a high sequencing dependency.

The case company's planning environment has two restrictions to its planning environment that is not asked for in the planning environment-identifying framework:

- (i) Set-up times are a special issue in this context and a key characteristic that needs further consideration. For some of the dedicated tools it takes several hours to prepare them due to their complexity. Furthermore, the applied toolset is a significant cost factor which is owned by the car manufacturer, but designed, built, applied, and maintained by the case company.

- (ii) Since tools and equipment used to produce a product are the same during the serial and the spare parts phase, the planning methods cannot be completely separated for the two product groups, but need to result into a single production plan for each line.

3.3 Current planning approach and its challenges

In the investigated case the applied planning approach can be described as a utilization of the long-term and short-term planning horizon [4, 24].

At the MPS level, the company performs a high-level material requirements planning approach following a make-to-order strategy. Figure 2 describes this planning approach in more details.

At first, after the receipt of a customer order, the enterprise resource planning (ERP) system performs the related offsetting and netting. Afterwards, this is controlled manually by the logistics department in terms of capacity restrictions and is adjusted. For each main process a 4 weeks production schedule is created based on the data in the ERP system. This schedule is seen as a 1+3 weeks planning schedule. The first week describes the production schedule that is planned to be executed. The plan for the rest weeks is more a forecast, as it is very likely to receive changes for the orders until the execution of the plan.

In the second step the planning is directly taken to the shop floor level by following the push principle. Based on this 4 weeks rolling production schedule, a daily production schedule is created every morning. A second and final offsetting, netting and capacity balancing is done, based on detailed shop floor data. This incorporates also rescheduled delivery dates, specific set-up times, physical inventory and the actual availability of operators and machines. On this detailed level of planning, this is in the responsibility of the executing department manager on the shop floor.

Table 2 Planning hierarchy level of the investigated planning methods

MPS level	Shop floor level
MRP	
ROP	ROP
Cyclic planning	Cyclic planning
	Heijunka
	Kanban

Summarizing the key characteristics of the case company, the planning environment needs to deal with a special product lifecycle. Serial parts need to be produced with high volume in the same production environment with spare parts with low volume.

This make-to-order approach utilizes dedicated tools for each product that require very long set-up times in order to produce the completely customer specific products that have a time distributed demand. The high manufacturing mix and the large variety of volume result in the following challenges for production planning:

- (i) Changes in demand and production breakdowns cause frequent plan changes and rush orders.
- (ii) Focus on high resource utilization and large batch sizes results in subsequent high inventories.

4 Discussion

In this section, we discuss the applicability of the selected five planning methods in light of the specific context of the planning environment of the case company (see Table 1) in order to investigate which planning methods are suitable in this specific case.

The selected planning methods find application on different levels of the planning hierarchy, which is most commonly subdivided by the time horizon of planning. Referring to Ref. [24] such a system contains a long-term, high-level planning like the MPS, the mid-term, detailed requirements planning, and the short-term, low-level shop-floor planning. While MRP is only applicable on the level of master production scheduling, ROP and cyclic planning are possible to utilize on the MPS, but also on the shop-floor level. However, heijunka and kanban are only applicable on the shop-floor level. Table 2 groups the investigated planning methods according to the planning hierarchy levels.

4.1 MRP

In the specific context of the case company's planning environment it is beneficial that material requirements are

specified in what needs to be purchased and manufactured. Thereby MRP provides control of the amount and the deliverables of required materials for the end product. MRP builds thereby on the MPS, the bill of materials (BOM) and the inventory file [25]. MRP/MRP II is the best suitable in complex scheduling situations with high levels of sub-assemblies and components according to Ref. [26]. The method is appropriate if the company has a sufficient overview on lead times and inventories and operates with stable and predictable demand [27]. This fits the characteristics of serial parts. Spare parts do not fit this description.

MRP does not consider the available capacity [28, 29]. It requires the use of an additional tool for CRP. However, MRP II combines MRP with the MPS and the CRP [19] and therefore erases the problem. Furthermore the method requires investment in ICT, particularly when used in form of an ERP system and moreover because of the complex and vast amount of data needed to be analyzed and processed. As the case company already deploys MRPII, the investment is not of relevance. Another disadvantage is the missing flexibility and responsiveness when confronted with changes in demand [27]. This is the case for spare parts. Finally, MRP/MRP II becomes very extensive when confronted with many variants due to the amount of data captured and processed in the system. As mentioned earlier, the company produces variants with an increasing trend.

4.2 ROP

One advantage for the case companies planning environment is that ROP ensures availability, one of the performance objectives of the case company. It enables continuous flow of production due to available inventory. The resource utilization can be optimized [30].

Adversely, it requires consequently predictable demand and order lead times [31]. This is the case for serial parts. Spare parts on the other hand side have unpredictable demand. Furthermore ROP requires a buffer safety stock [32]. The calculation of such safety stock seems to be of complexity considering the number of variants and the different demands of the two product types. In addition a predictable throughput time is required [25], which is hard to realize in the analyzed planning environment. The same applies for required inventory information [25, 30], especially in the context of spare parts. ROP builds on historical demand data and forecasting models [25]. For spare parts even having historical data will not help improve planning due to the unstable and unpredictable demand.

4.3 Cyclic planning

In the context of the case company planning environment, the dedication of processes to specific products allows a

higher capacity forecast accuracy and also a higher capacity and resource planning accuracy. Accordingly, delivery dates become predictable and a high product mix addressable. This suits the requirements of the product: delivery reliability and delivering a high mix. Cyclic planning is able to handle different batch sizes and product mix. This is highly suitable to the requirements of the identified planning environment. A repeated plan matches constant call offs and can therefore ensure the needed resource utilization [33], but can also handle the volume variation in demand for spare parts when producing those parts in free time slots. The method is able to increase the responsiveness [34] and therefore contributes to the performance objective of availability. In addition it is able to consider the sequencing dependency [34]. Case studies of applying cyclic planning in different industries show a certain extent of applicability in the environments with dynamic demand [35, 36].

One key element for cyclic planning is the equipment flexibility. The case company has production lines with long setup times but has also flexible lines. The equipment is built to enable flexible routing. As such, equipment flexibility can be assumed to be given to a certain extend. Another key element for cyclic planning is the production system capacity [34]. The company currently uses for instance overtime to ensure the availability of sufficient capacity in peak periods. Sufficient capacity could be assumed to be given. Cyclic planning creates flow lines with temporary dedicated machines. That is positive in the first place as it fits with contracts and delivery agreements, but with the long changeover times in the production in mind this could lead to inefficiency.

4.4 Kanban

Applied to the planning environment of the case company, kanban implies that only needed parts are made in order to cover the concrete demand. Consequently, kanban avoids overproduction [37]. Considering the vast amount of capital bound in finished goods inventory due to the current high volume production mode, this is a favorable aspect. Kanban aims for shorter flow times and a reduction of inventory [13]. Both aspects are positive for the case company in order to reach the performance objectives of availability and delivery reliability. Besides this, it is beneficial that the planning method requires less planning effort as it is a self-organizing system.

A major limitation is the non-applicability with long setup time [22]. As stated above, there are currently relatively long setup times in the production process. In order to apply kanban, there would have to be a reduction in changeover time accordingly. Furthermore kanban requires the reduction of demand amplification [22]. In the case of

spare parts, this will be only possible to some extent as the nature of the demand is unpredictable. The effort to create a stable work plan through standard work [22] would also have to be considered. This will be simpler regarding the demand characteristics of serial parts and tougher regarding those of the spare parts.

4.5 Heijunka

An advantage in the context of the case companies planning environment would be that heijunka aims at reaching a higher average resource utilization and smoothing the resource utilization [38]. Furthermore, heijunka enables to have a high level of schedule visibility [39]. Thereby the company will be aware of problems early on. Heijunka also generates a cyclic and constant production mix [38]. This is favorable considering the specific requirement of the case company to produce spare and serial parts in the same production environment. The method evens out peaks in the quantities produced [38]. This is an advantage considering the unstable and unpredictable demand for spare parts and the challenges that creates for the company.

Constraining in the context of the case is that heijunka assumes that changeover times are negligible [39]. In this case, set-up and changeover times are high and need to be considered. A heijunka production plan does not follow a given sequence of orders, but batch orders of a specific period of time. This could contradict the requirement to have a high availability, such as to deliver spare parts on the required level of responsiveness. Furthermore smaller lot sizes are in this context a key aspect for higher utilization using a mixed-sequence scheduling [40]. The method smoothes requirements to a uniform level. This will be a challenge regarding the spare parts demand pattern.

Each planning method was analyzed in the context of the specific case and evaluated in terms of resulting advantages and disadvantages. Implications are made as a part of the next section.

5 Conclusions and further research

This paper has discussed the applicability of methods for production planning and control to the specific planning environment of a producer of aluminium car parts. ROP and kanban have been found inappropriate for the demand characteristics of the case company. In addition a strict cyclic schedule would be difficult to implement, especially due to irregularly arriving spare parts orders. Heijunka is more flexible in this respect, but it requires short changeover times and is thus not easily applicable in the present context. MRP has the advantage that it directly responds to

customer demand and inventories are kept low. On the other hand, it leads to nervousness and instability in the production system, which is challenging when changeover times are long and equipment inflexible.

In conclusion, several methods contain desirable features, but none can properly address the planning challenge of the case company. Traditional approaches of lean planning, such as kanban and heijunka, seem to work mainly in assembly environments. There is thus a need for further research to develop alternative approaches to production planning, properly addressing the characteristics and challenges of production systems such as the case companies with its long set-up times. These alternative approaches should strive for stability and predictability on the shop floor, while at the same time offer the flexibility needed for spare parts production.

For further research it is also of particular interest how the planning environment not only of the forming process could be addressed, but also how this could be realized in coordination with the upstream manufacturing processes, covering the complete internal supply chain. Related to this, the control model in Ref. [41] could be applied to characterize the greater picture of the manufacturing and planning processes. This could lead to a new concept for the coordination and synchronization of master production scheduling and shop-floor scheduling in planning environments characterized by multi-echelon manufacturing environments.

Furthermore the support of ICT for these kinds of planning environments should find further investigation. Once a fitting approach of planning is identified, a possible direction of future research could also be to investigate how optimization could be utilized for more efficient planning.

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