PRODUCTION PLANNING AND PRODUCTION LEVELLING

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Abstract

Production planning is very important subsystem of the production system in any manufacturing company. Therefore, its efficient operation is very important and must be paid to it an adequate attention. The aim of the paper is to show and explain on a real example of manufacturing company in Slovakia how such subsystem functions and what different tasks must be accomplished so that this subsystem works effectively not only within manufacturing company itself, but also in relations with suppliers and, mainly, with customers. A case study approach was used as the scientific methodology to demonstrate on the real example the running of this subsystems and possible application of demand levelling (or production levelling) tool within the existing production planning subsystem.

Keywords: production planning subsystem, manufacturing, production levelling, process improvement

Introduction

The current competitive environment means that enterprises have started intensively to address the efficiency of its own activities. Thanks to investments in new technology and information systems and the design of new products when having own design department companies prepare a suitable ground for future results, but as such, they are not enough. Equally important is the effort for continuous improvement of its own effectiveness, cost, and quality. The new center of attention has become the concepts such as added value, value-added activities, waste, and customer orientation.

The goal of each manufacturing company is to achieve the economic effects that flow from the invested economic effort. This effort is spent by different ways and for different business priorities. One of them is considered the variability and flexibility of the production system. Any manufacturing plant cannot further rely on a steady and constant production of certain product portfolio that is not able to flexibly respond to changes in customer preferences. The fact that there are a number of competitive and substitutive products on the market, the demand for specific products often exhibits a much higher volatility than in the past. Therefore, the manufacturing companies, when creating production plans or schedules, must focus on the fact that plans in case of a drop in demand for one product and a growth in demand for another product enable to achieve the necessary quantities of production volume.

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while there is no overproduction of products without in advance known expected sales of products. Modern approaches to production planning include production levelling from the lean management concept to contribute to this approach significantly.

In the literature dealing with the lean production as it relates to production planning, only the application of production levelling is described. While production levelling is undoubtedly a useful tool, a real state of production planning in the manufacturing company is more complicated, we cannot concentrate and limit it only to the introduction of production levelling and think that production planning as a whole will work efficiently, not only in itself, but also in conjunction with other production subsystems as well as between customers and suppliers. The aim of the article is, therefore, to describe the way of how the production planning subsystem works on the example of the real production organisation as a case study, which could serve as a basis and inspiration for other production companies in Slovakia.

1 Methodology

First, current literature sources about production planning methods and production levelling tool were reviewed using on-line databases. The aim of the practical part is to analyze a current way of production management and mostly production planning in the large manufacturing company. Information about the presented topic in a particular company has been obtained from the real practice and manual processing of the company documents in the production system itself and also from production planning subsystem that are described on the example of one selected plastic product made in that company. The entire process required the collection of many data and information from the company’s real production activities and activities regarding production planning department.

The whole process went through a detailed analysis of the internal company materials gathering documents from the various units, then by interviewing employees in the production planning department while observing production running personnally.

The result of the whole case study is the thorough description of the contemporary procedures of production planning subsystem and how it effectively works within the whole production system. The described process can serve as the model for other companies of similar size and branch.

2 Literature Review

Production levelling (in Japanese called heijunka) is a concept used in the Toyota Production System (TPS) for the settlement of work schedule, which means the system stabilization and creating of equilibrium – a truly balanced lean workflow. When production levelling is used in the literature dealing with lean management, it expresses a technical term of TPS. The English translation is “levelling” meaning levelling both the amount and the mix. Production levelling thus means levelling the type and quantity of production over a fixed period of time. The achievement of production levelling has fundamental importance for the production system. Production levelling enables production to efficiently meet customer demands while avoiding batching, resulting in minimum inventories, capital costs, manpower, and production lead time through the whole production system. The unbalanced production
schedule, which is manifested by frequent imbalances in production run-up and its subsequent interruptions, or by excessive and, at other times, inadequate use of production capacity, does not give space for accomplishing quality, work standardization, increasing the productivity or to the utilization of continuous improvement system.

Production levelling is often cited and explained in the literature belonging to the TPS or lean management. Production levelling is the process where, in mixed-model production lines, product units are properly arranged, rather than manufactured in a random order, to minimize the variations in parts consumption and workload at the workstations. Thus, production levelling has been used to optimally sequence various product models (or product variants) during manufacturing so that the peaks and valleys in demand for products are smoothed out across the planning period to enable overall cost reductions and improved efficiencies.

So far, the technical aspects of the production levelling problem have been widely explored. However, Toyota’s approach to production levelling appears to be much broader. Marksberry points out at this view well and suggest that in production leveling we have to focus beyond just the manufacturing department; and integrate the technical systems with the management systems for successful production leveling.

Often in articles, different mathematical models are presented to help with them planning of the production systems. Or other authors utilize group technology to develop intelligent production planning algorithm. And recent articles are even focused on utilizing data envelopment analysis for this purpose. However, the production planning is a more complex subsystem in manufacturing companies and cannot be constraint only to some mathematical models or algorithms, even though, they can be beneficial.

3 Production planning subsystem - case study approach

3.1 Introduction of the company

We will call the analyzed company as Plastik company s.r.o. (further Plastik company), which is a large companies established in the Slovak republic and operating in the sector (industry) of plastic moulding and modifications.

Primary activities are split up into:

- production of plastic mouldings – mostly plastic covers and parts for TV sets, monitors, set-top boxes, and parts for the automotive industry
- production of polystyrene packaging materials.

In terms of the sectors in which customer companies operate, the production system of Plastik company can be divided up into the production for:

- black and white technique sector
- automotive sector
- other sectors.
In this paper, we will focus on the production system, which manufactures products for customer company producing TV sets. Therefore, the products belong to the sector of black technique, and constitute specific components for TV sets. The manufacturing process, that we’ll focus on, will be the extrusion of plastic mouldings.

3.1.1 Characteristics and division of the input material

In the Plastik company, input materials are divided up into 3 types in terms of when and how they enter into the manufacturing process:

- before manufacturing process - resin granules,
- during manufacturing process - small party,
- after manufacturing process - packaging material.

Resin is a raw material in the form of granules, which is generated during the processing of crude oil. In the industry of plastics pressing, it is used as an input to the injection molding machines. We know a number of plastic resin types that can be categorized according to their chemical composition, and the chemical composition determines different characteristics of the behavior during processing and different characteristics and quality of the outputs. Depending on what features we require from a plastic product, only that material is used, which ensures these properties. For products that Plastik company produces for its customer, exactly that type of plastic resin is set, which should be used for the designated product.

The name ,,small parts“ can be partially confusing in translation, since it represents always the small parts. In general, however, we characterize them as parts or components that the company orders and purchases from suppliers for the purpose of their subsequent assembly into the in-house produced plastic molds. They can be, for example, bolts, touch TV panels, wallholders (TVs on the wall), lensled (signal light led of TV), speakers, assy boards (electronic boards integrated into the TV frame), but also larger parts, which can paradoxically create the very basis of the product.

Packaging material represents by the customers approved types of packs, in which the finished products are stored before their shipment to the customer, but also semi-finished products in their transfers to the following processes.

3.2 Production plans of the customer company

The production system itself and manufacturing processes require thorough and efficient method of production planning. It means that we need to know the principles of creating production schedules. Since the Plastik is a supplier company, its production plans must strictly follow the requirements and orders from their customers. In our case, customer company provides Plastik company several types of production plans to serve as a guideline for Plastik to make its own production plans. Depending on whether that is a production planning of new project, or production planning of ongoing project already, it is necessary to carry out various operations, for example capacity planning of machinery utilisation, planning
of human resources, order planning of input materials, planning of modifications of injection molding machines, and many other things.

At the beginning, we’ll begin with the production plans of the customer company. Customer makes 4 types of production plans, which sends to its suppliers for their own needs. They are:

**GO annual production plan**
- is created always in November, and that month is also shifted to suppliers;
- in December, customer company convenes the directors of supply companies in order to present them prototyping models of products that are intended to be produced in the following year according to these plans;
- its primary aim is to plan the production of new models, but it also includes production plans for ongoing models;
- is divided into months, where a planned production volume of each model is shown;
- is only indicative, it plans only approximate volumes according to the expected demand of the final sellers (once a year, customer company calls final sales representatives – up to 18,000 sales outlets in Europe, whom new production models are presented, and they express their own preliminary demand for individual months);
- takes into account seasonality: during the season (High Season), outside the season (Low Season) + periods of major sporting and cultural events.

**High season:**
- since the middle of March to the beginning of April / May (increase of the production volume of those products, which at the beginning of the year have seen an interest of future customers at the exhibitions in the United States and Germany);
- from September to the half / end of December (increase in output due to the coming public holidays).

**Low season:**
- from June to August;
- from January to the mid / end of March;

**Period of major sporting and cultural events:**
- for example, there is expected a significant increase in demand for TVs during the football World Cup;
- planned increase of the production volume is visible about cca 2 months before the event;
- the purpose of this plan is to provide suppliers with time for possible investment aims, which are related to the production of new models (e.g. when future production requires capacity increase or investment in new technologies);
- Plastik company allows investments up to 1 million euros for a new project (cca 4.5 to 5 million euros yearly to all projects).
Long-term 16-week production plan (FORECAST plan)

- is more accurate forecast of the dealers’ planned enquiries according to individual weeks;
- is divided by weeks from WEEK 1 to WEEK 16, where planned volume of individual models is set;
- serves for more specific preparation of production (recruitment of new staff, training, introduction of new manufacturing procedures, technical preparation of production, purchase of the necessary equipment for manufacturing and so on);
- Plastik company on the basis of this plan makes its own long-term production plan, and, depending on the quantity, complexity, and the production capacity, the company begins with preproduction of products (producing in advance).

Weekly fixed production plan (FIXED plan)

- is a fixed, i.e. agreed production schedule of the products for the following week;
- represents so called the customer company order for production of the necessary parts by its suppliers;
- is made every Tuesday at the meeting in the customer company, where the customer invites its suppliers to discuss their current production status and options and the ability to supply those parts in the next week;
- is valid from Wednesday morning, because it provides some time for any corrections.

Daily plan of orders (DO plan - Daily Order)

- regards the real goods order with the terms of delivery quantity, in a given day, and in a given hour - JIT delivery;
- is always sent to the suppliers 3 days before the date of delivery, this means: on Monday to Thursday, on Tuesday to Friday (possibly on Saturday, if it is produced), on Wednesday to Monday, on Thursday to Tuesday, and on Friday to Wednesday.

3.3 Production planning in the Plastic s.r.o. company

Production plans of the Plastik company are divided up into long-term production plan, weekly production plan, and daily plan of deliveries. As the title suggests, the first plan will be generated according to FORECAST plan, the second plan according to FIXED plan, and the third plan according to DO plan. However, before the company can create any plan, it is necessary to have the Plan of plastic mills available, which is a part of the above mentioned plans.

The plan of plastic mills is drawn up at the beginning of the year, when for the Plastic company all technical documents for the new year’s model are available. The purpose of the plan is a division of products into product groups for each injection molding mills. This means that the technical specifications of the new models are analyzed regarding what types of injection molding mills are necessary to produce these models. Then, for each injection
molding mill a group of products is assigned, which includes new and old models provided they are to be produced in a given year.

A long-term production plan (COVERING)

A long-term production plan is directed according to the FORECAST plan and is constantly updated. It takes into account complete product mix for each week, and its integral element is the plan of plastic mills. This plan is often referred to as COVERING.

COVERING is a set of several tables, in which for every week the volume of products, volume of material, and the capacity of utilizing injection molding mills is planned. In the first table with the same name, each of the products are listed in the rows, and each of them, the current volume of the product in the store and the necessary volume for specific weeks (WEEK 1, WEEK 2, WEEK 3, etc.) in the columns is assigned. With blue color, those weeks are marked that are "covered" by the stock volume. In the second table named CAPACITY, capacity calculation is made for the utilization of individual injection molding mills, injection molding mill groups, as well as of the entire mill shop for individual weeks. It contains information about:

- individual injection molding mills (sorted into groups according to the clamping forces),
- products (sorted into injection molding mills),
- the necessary product volumes for individual weeks (according to the FORECAST plan),
- maximum daily production volume (for each product on respective injection molding mill),
- capacity calculation of the utilization of individual injection molding mills, injection molding mill groups, and injection molding mills together (for specific weeks).

The third table MATERIAL shows the coverage for resin granules for individual weeks according to the FORECAST plan. In it similarly to the COVERING table, there are sorted out particular types of resin granulate, their current stock in the warehouse, and the necessary volume for specific weeks.

The aim of long-term planning is to plan and coordinate the production of individual products on the individual injection molding mills so that from each product, it would be produced in advance such a volume which complies with the principle of W + 1. It is, therefore, necessary to hold a stock of finished products, which will cover the current and the following week. In principle, however, it is producing in advance for a longer period, which is most evident with products with small sales in the upcoming weeks. Indeed, it would be time and cost ineffective to insert and put down the mold to and from the injection molding mill or doing changeover only for the small production volume.

In addition, it is necessary to take into account the frequent volume fluctuations between the FORECAST plan and FIXED plan. It is quite common that when the FORECAST plan has product volume specified for a given week, in the FIXED plan, completely different volume may be assigned for that week. The reason for this can be that for
the production of some product several suppliers are responsible, and if a problem arises with
one supplier, its volumes are allocated to the second supplier or are calculated to others. It is,
therefore, necessary to predict the possibility of such a situation and to plan preproduction
with the coverage for longer period than W + 1.

1. The fact that it is not necessary to operatively prefer the production of same product at the
expense of the planned product, long-term production plan will not be undermined.

2. We prevent the occurrence of situation, in which we due to unexpected fluctuations are
technically (limits of injection molding mills) unable to cover the required volume.

Principle W+1 is, therefore, the minimum that is required from long-term plans, and
only in certain reasonable situations it is possible to hold this "little" stock for certain
products.

**Weekly production plan (WEEK plan)**

The weekly production plan or schedule is based on the planned COVERAGE and
FIXED plan. This WEEK plan modifies production for a given week only when a bigger
difference between FORECAST and FIXED plan arises. This means, if volumes in the
FORECAST plan for a given week were identical with the volumes in the FIXED plan, there
is no need to change the scheduled production. In this case, actually required volumes
coincide with the planned COVERAGE that this volume already produced in advance.
However, if the FIXED plan comes to volume increasement, which is a more common
situation, in the first place, storage volumes of finished products, the technical limits of the
week production, capacity utilisation of machinery for a given week, the stock volumes of
input materials and others are finded out or checked.

Week plan, therefore, often works on the principle of operational measures. This
means that often in a given week, injection molding mill is changed over, in other words one
form or mold for another is changed over. This, however, means downtime and after starting
to run injection molding mill, for some time until the injection process is stable, production of
scrap. It is due to the technical aspects of the pressing process. Overall, however, planners
always try to make sure the form in some injection molding machine would be as long as
possible, because it prevents incurring the hassle and production time of this machine is
effectively utilized.

**Daily plan of shipments**

It is the plan, by which the goods to be shipped according to the DO plan or schedule
are prepared. The department of logistics is governed by this plan, which controls the status of
each warehouses of the finished products, and according to this plan, it controls and
dispatches the goods to the customer according to the Just-In-Time principles.
3.3.1 Meeting about FIXED plan
Meeting is held every Tuesday in the customer company and the Plastik company sends there its project manager who is responsible for the provision of information about the planning of this production. For the purpose of approving the weekly fixed production schedule of the customer company and the development to this subordinate WEEK production schedule of the Plastik company, the project manager needs to have available the following internal information:

- Inventory status
  - what quantity of which product the company has in the warehouse of finished products (i.e., preproduced pieces), in the warehouse of work in process inventories, and in the warehouse of the input material (i.e. plastic resin stocks, stocks of small parts and stocks of packaging material).

- Status of delivery from the previous week (according to WEEK plan of the Plastik company)
  - what is the status of the customer company order fulfillment from the previous week, it means, which orders need to be treated from Tuesday through Friday (or Saturday).

- Status of long-term production plan of the Plastik company
  - what is the status of long-term production plan of the Plastik company, which is directed by a long-term 16-week plan of the customer company (FORECAST plan);
  - what quantity of which product the Plastik company has preproduced, i.e., what is the "coverage" of various products and what products are planned for production in the negotiating week according to this plan.

- Status of machine and equipment capacities
  - what is the utilization of machines and equipment;
  - If the volume of products required in the customer weekly fixed plan has increased in comparison to the long-term 16-week plan (FORECAST plan), is it possible with the current production capacity this quantity to manufacture, or produce it in advance by the following week?

- Other necessary information about the production
  - production cycle (cycle time) of injection molding machines (if necessary for the calculation of maximum daily production of a certain product);
  - information about possible problems in production (for example, the problem with the form of injection molding machine), which may lead to the impossibility of further production of the product concerned.

3.4 Planning of orders for incoming material
Order planning of the input material is a part of production planning. There are about 3 types of input materials: resin granules, small party and packaging material, while the first two types are further categorized according to the ordering method – let’s call them Part Group 1 and Part Group 2 materials.
The purpose of such a material categorisation is to reduce the total costs of production. Part Group 1 materials include small party and resin granules, which as an intermediary in their ordering is the customer company. Those are mostly the types of plastic resin and the small party materials, which are used worldwide in all other similar plants of the customer company, as well as in its suppliers. The fact that the customer company serves as an intermediary, or sometimes even a direct purchaser of these materials, the purchase price of Part Group 1 materials is due to the huge purchases significantly lower than it would be in the event of the purchase only of the Plastik company alone.

**Ordering of the Part Group 1 materials**

These materials are ordered according to their actual consumption and consumer forecasts (weekly to monthly). In this case, the Plastik company is obliged to send the inventory physical check of its material warehouses on a daily basis to the customer company. In view of this situation, the customer company analyzes the statuses of other suppliers and its own and, if necessary, to:

- reorder materials into its own warehouses, from which it delivers to the suppliers (if the customer company is a direct purchaser).
- order materials to the warehouses of suppliers in agreement with them (if the customer company is an intermediary).

In the case, the customer company is a direct purchaser (which happens most often with the resin granulate) and then this material is stored in its warehouses, the advantage of Part Group 1 materials is:

- a quick delivery time (usually 24 to 48 hours),
- no need to hold them as a long-term supplies.

**Ordering of the Part Group 2 materials**

Those are input materials, which the Plastik company orders and purchases on its own. With small parts, suppliers are most often Slovak or Hungarian companies that directly produce them, but with resin granulate, Asian companies are a producer. Planning of these materials is then based on the suppliers’ lead time, which is the time the vendor needs for a supply. The lead time for small parts is a few days and for the resin granulate often is several weeks. Therefore, it is important to send the long-term production plans to the vendors regarding resin granulate, in which for each week, the necessary volumes of plastic resin are defined. On the basis of these plans and lead times, the vendor acts in a way that some material should be available in a given period for the Plastik company. The order for the supply of this material is then always sends a week earlier, as the company wants to have it in stock. The company in this case follows the W+3 principle, which means that the material has to be physically in the company at least 3 weeks before the production use.
In our case, we will not describe ordering of packaging materials, because due to the different characteristics and each type of production, it goes about very specific conditions under which such packaging materials are ordered.

3.5 Possible Production levelling application

Drawing up production schedules in the Plastik company is a complex process, which is closely related to the production plans of customer company. However, we cannot talk about levelling, as it is defined in the theory on production levelling, in particular when it comes to the schedules for producing plastic parts. It is given by technical limitations of moulding process itself, when it is inefficient to change the manufacturing program of injection moulding machine during the day or several days. It is also due to the frequent volatility of volume required by the customer, when demand for one product in one month radically drops and for the second product sharply increases. Here, levelling can be understood only in terms of efforts to maintain the necessary quantity of stock relating to the FORECAST plan. The aim is, therefore, to level the production schedule from the perspective of a couple of weeks (it can also be much less, and much more depending on the volume and the number of products for injection moulding machine), when all products on these injection molding machines will be changed, while the last machine has produced in advance (to the stock) a reasonable amount of products, so that the product could be produced (pressed) whose volume in stocks, by contrast, has fallen below the required level.

However, some levelling based on production levelling tool can be achieved and is actually achieved, to some extent, in the assembly process. The reason is that these products have relatively stable and balanced sales volume, which differs only in product mix, and, therefore, it is possible to plan a balanced schedule. The assembly, as well as moulding process, takes place throughout 24 hours a day in two shifts. Each shift has its own schedule defined (that is, what and in what quantities it is necessary to produce), according to which the heads of the shift manage production, while these schedules are balanced in terms of the weekly period. There are then no excessive inventories of assembled products, or risks stockouts. There is rather a room for the achievement of stable quality, the possibilities of work standardization, productivity increasing and using the system of continuous improvement. In addition, in the event of a sudden need to assemble product of different type, changeover is considerably easier with much lower time and cost losses as when changing forms of injection molding machines. It is important to say that the schedule of assembly line can be balanced, in particular, due to partial independence from the moulding process. It is due to the fact that a buffer stock supply is created, which ensures a steady, even though timely limited supply of material to assembly workers regardless of whether injection molding machines currently are working.

Conclusion

The utilisation rate of the principles, methods and tools of lean manufacturing like production levelling in the Plastik company can be assessed as significant. Where it is possible within the specifics of that production, i.e., technical, organizational, and customer conditions, the company seeks to apply everything that leads to a greater degree of leanness.
Leanness is here understood as greater flexibility, and it is the most important factor for achieving a strong competitive position of the Plastik company.

On the other hand, it is possible to see partial discontinuity in the implementation of improvement proposals within various departments. Each department comes with its own proposals for improving independently of other departments regarding production levelling too, and these could be applied in a greater or lesser degree, or in more or less modified form. The company lacks a comprehensive system that would combine departments and units with the aim of bringing improvements in categories according to the areas that are currently under improvement. By creating such a system, the faster application of cross-cutting innovations could be achieved that would improve the processes in all departments evenly.

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