

OOPUS

A Production Planning Information System to Assure High Delivery Reliability Under Short-term Demand Changes and Production Disturbances

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Abstract: Batch-sizing and scheduling is the central decision problem in the area of production planning. A special challenge in this context is to handle the big amount of data in an adequate time interval. To aggregate and to illustrate this data clearly, appropriate techniques are required. This paper presents a new approach to integrate a Production Planning Table visualized by a Gantt chart and a cumulative quantity table for maximum information transparency in production planning. The discussed solution is realized in OOPUS, an object-oriented tool for planning and control, which became the leading production planning system in two motor assembly plants of an international automobile manufacturer.

1 INTRODUCTION

The last years in the automotive industry were affected by a strong trend towards decreasing life cycles of products and at the same time increasing time of innovation ongoing with a continuous diversification of the product range. Furthermore the pressure of competition increased dramatically due to weakened purchasing power of customers, a decreasing customer-specific brand affinity and permanent changes of the market and customer requirements (Harjes et al., 2004). In order to stay competitive, automobile manufacturers have to produce their products in high quality and at low costs in even shorter time. A crucial meaning to withstand these challenges belongs to ERP systems, which control, standardize and optimize the business processes along the whole value chain (Holland and Light, 1999). An essential factor to achieve this goal is the batch-sizing and scheduling. To satisfy the changing demands the existing schedule has to be adapted regularly. Under the objective of minimizing the production costs and stocks, batch-sizing and scheduling is a complex problem.

Depending on the type of production there are many factors to be considered. These could be time-dependent demands, capacities of production lines, stocks, buffers, qualifications of workers, set-up- and lead-times, stockouts, backlocks, alternative or parallel identical machines, batch size and transport restrictions as well as different shift calendars (Tempelmeier, 2006; Stammen-Hegener, 2002). Based on the resulting production plan, demands of secondary and tertiary parts can be derived and the capacity utilization analysed. If necessary, it should be possible to adjust capacities within a short time. In order to cope with this challenge, data from several sources has to be related to each other and to be presented to the user of an ERP system.

In the following a holistic solution for this problem, called OOPUS (germ. **O**bjektorientierte **P**lanung **u**nd **S**teuerung - object-oriented planning and control), will be described in detail. This information system was developed to meet the specific requirements of an international automobile manufacturer. Nowadays OOPUS is the leading production system within two plants.

2 PROBLEM DEFINITION

Production planning is a two-step process (see Figure 1). First, suitable batch-sizes have to be determined based on time-dependent demands. Then an optimal schedule has to be generated.

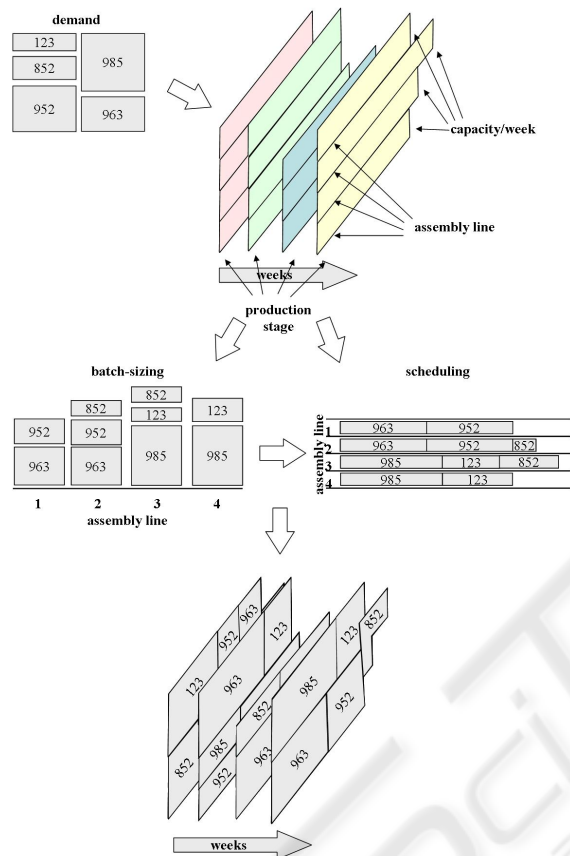


Figure 1: Process of batch-sizing and scheduling.

To determine appropriate batch-sizes in OOPUS, the Multi-Level-Capacitated Lot-Sizing Problem (MLCLSP) (Katok et al., 1998; Tempelmeier, 2003) has to be modified. On the basis of a standard-MLCLSP, extensions like parallel identical machines and the initial and final inventory are required.

The MLCLSP is an np-complete problem and can therefore not be solved with an optimizer in appropriate time (Maes et al., 1991). Hence, a suitable heuristic has to be designed.

Due to the changing capacities of machines scheduling is also a very complex problem. Each shift of a batch requires a recalculation of the batch length and the completion date. Under the requirement of optimal scheduling subject to set-up times and stocks, this problem can not be solved

with an optimizing algorithm. For this reason, an appropriate heuristic (like a priority rule procedure) is required.

Due to these heuristics and the multiplicity of not forecasted influences (e.g. urgent orders or changes of demand quantities) this information has to be represented transparently. This enables the responsible planner to reconstruct and manually reschedule the production plan in an adequate way.

Production planning systems are characterized by an enormous complexity of information which is often distributed in different isolated software solutions. But this complexity not only arises because of the quantity of all relevant elements, but in particular also from their mutual cross-linking. Without an adequate information system, this complexity implicates high requirements of the users ability to collect and integrate information and to evaluate and plan actions. Hence it is decisive for an easy handling of this complex data that it is presented in an aggregated and clearly arranged (i.e. user-friendly) form. Beside the aggregation and visualization of this data, the timeliness of the data is also critical. For this reason the data have to be synchronized in real time with the different sources. This ensures a reliable planning and an adequate change management.

3 STATE OF THE ART

3.1 Getting an adequate ERP System

The market consists of a multiplicity of standardized ERP systems, which offer solutions for a large part of production planning and control tasks, such as requirement planning, batch-sizing and scheduling and stock-keeping. However, analyses of these ERP systems in detail shows some disadvantages. The standardization of the planning procedures of a production system often does not correspond exactly with the functionality required by the customer. Adjustments of these procedures are often not possible or very expensive and time-consuming.

Apart from costs based on consulting and implementation activities, further costs of worker qualifying measures evolves. Additionally, the standardization of software often implicates a bad usability concerning special requirements, which can affect the acceptance of the system and increases the qualification time, especially of inexperienced users.

Another problem is the integration of a standardized system into an existing IT-landscape. Especially in big enterprises the IT-landscape often

consists of a large number of different isolated software solutions, which mostly cannot be changed completely due to the current economic situation.

3.2 Representation of Planning Data

There exist different concepts for appropriate representation of planning data in ERP systems.

Most providers of ERP systems use Gantt charts for displaying a schedule graphically (Wilson, 2003). A Gantt chart consists of a horizontal bar chart with time intervals and either resources, operations or orders as the vertical axis. Individual operations (e.g. batches) are displayed as horizontal bars in the chart, indicating the time at which the operation begins and ends. The disadvantage of a Gantt chart is that at a large number of batches the representation is not clear and it is very difficult to get information about the entire processing status.

The cumulative quantity concept (Schönsleben, 2004) is a representation used in serial production to show changes of dates and quantities clearly. The concept is based on cumulated parts, related to a certain time (e.g. an inventory deadline). By these cumulative quantities, planned and actually realized quantities of parts can be compared. The difference of the target cumulative quantity (TCQ) and the actual cumulative quantity (ACQ) points a quantitative advance ($TCQ < ACQ$) or a quantitative deficit ($TCQ > ACQ$) in relation to the given demands. Particularly in the case of planning and controlling large quantities of parts, the use of cumulative quantities is a suitable concept (Kurbel, 2005).

4 OOPUS

Based on the requirements defined in chapter 2 the software OOPUS has been developed. Thereby experiences from an earlier project called OOPUS-DPS (Dangelmaier et al., 1997/99), which operates successfully at a big automotive supplier since a few years, were used. A detailed description of the underlying model that fits all specific requirements would exceed the scope of this paper, but can be found in (Dangelmaier et al, 2007). As a main focus, a user friendly graphical user interface consisting of a planning table and a cumulative quantity table was designed to support the planner in all areas of his work.

OOPUS is realised as a holistic concept. First, data (e.g. customer orders, capacities of machines, etc.) from different systems have to be imported. On

basis of these data the automatic production mechanism generates a valid and loading optimal production plan, which regards every organisational frame condition like different planning areas or linked assembly lines (AL). In order to consider short term changes or special experiences of the planner, the responsible planner can adapt the automatically generated plan. This holistic concept is illustrated in Figure 2.

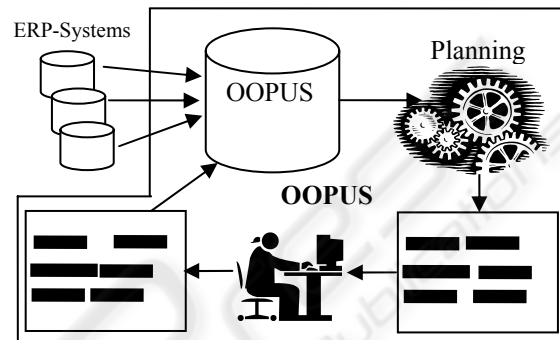


Figure 2: Holistic concept of OOPUS.

5 GUARANTY OPTIMAL INFORMATION TRANSPARENCY

One main issue of the software OOPUS was to present the large number of relevant data in a highly ergonomic way. The main approach to realize this was the idea of two functional split but data coupled graphical user interfaces.

The planning table displays the batches on their assembly lines over time in form of a Gantt chart in a concise way. The planner can directly change the plan by different batch actions like moving or changing the batch size.

The plan visualized in the planning table is shown in the cumulative quantity table (Figure 3) by its forecasted cumulative quantities where it can be compared with the demands.

5.1 Cumulative Quantity Table

The cumulative quantity table (CQT) gives an overview of the manufacturing program which has to be realized and of the manufacturing program which would be realized by exact adherence of the actual viewed plan. Thereby the planner is able to detect mismatches of planned and required product quantities easily. Exactly these mismatches have to

Vorgang/Linie	Sachnummer/Kunde	Abruf()	Kum. Kor. Ist	Diff	KW 25-	19.06.2006	20.06.2006	21.06.2006	22.06.2006	23.06.2006	24.06.2006	25.06.2006	KW 26+
ML 2					5	Ja	Ja	Ja	Ja	Ja	Nein	Nein	5
für: FS Versand					Soll-FSZ	0	0	0	0	0	0	0	150
038100019M S 1665			22		Soll-FSZ	0	0	0	0	0	0	0	150
				22	Plan-FSZ	22	22	22	22	22	22	22	30
					+	22	22	22	22	22	22	22	-120
					Soll disk.	0	0	0	0	0	0	0	150
					Plan disk.	0	0	0	0	0	0	0	8
					Plan d. Linie	0	0	0	0	0	0	0	8
für: FS Versand					Soll-FSZ	21	21	21	21	21	21	21	21
038100029PMS 1670			8		Soll-FSZ	21	21	21	21	21	21	21	21
				-13	Plan-FSZ	8	8	8	8	8	8	8	8
					+	-13	-13	-13	-13	-13	-13	-13	-13
					Soll disk.	3	3	0	0	0	0	0	0
					Plan disk.	0	0	0	0	0	0	0	0
					Plan d. Linie	0	0	0	0	0	0	0	0
für: FS Versand					Soll-FSZ	980	980	980	988	988	988	988	996
038100029QJS 1671			833		Soll-FSZ	988	980	980	988	988	988	988	996
				-147	Plan-FSZ	833	833	833	833	833	833	833	857
					+	-155	-147	-147	-155	-155	-155	-155	-139
					Soll disk.	1	-7	0	0	0	0	0	8
					Plan disk.	0	0	0	0	0	0	0	24
					Plan d. Linie	0	0	0	0	0	0	0	24
für: FS Versand					Soll-FSZ	296	288	288	288	296	296	296	304
038100029PMS 1691			150		Soll-FSZ	296	288	288	288	296	296	296	304
				-138	Plan-FSZ	158	150	150	150	158	158	158	166
					+	-138	-138	-138	-138	-138	-138	-138	-138
					Soll disk.	8	0	0	0	8	0	0	8
					Plan disk.	8	0	0	0	8	0	0	8
					Plan d. Linie	8	0	0	0	8	0	0	8
für: FS Versand					Soll-FSZ	3935	3879	3879	3879	3935	3935	3935	4031
038100029QJS 1692			2155		Soll-FSZ	3935	3879	3879	3879	3935	3935	3935	4031
				-1724	Plan-FSZ	2211	2155	2155	2155	2211	2211	2211	2307
					+	-1724	-1724	-1724	-1724	-1724	-1724	-1724	-1724
					S	61	5	0	0	56	0	0	96
					P	56	0	0	0	56	0	0	96
					P	56	0	0	0	56	0	0	96
für: FS Versand					Soll-FSZ	29	27	28	29	29	29	29	27

Figure 3: The cumulative quantity table.

be avoided, because they can lead to high costs. In addition to this information, several other parameters like free capacities of assembly lines or batch parameters are shown to support the planner in creating a plan which can hold the fixed dates for all orders.

Two different cumulative quantities are shown for each part number the planner is responsible for. On the one hand the target cumulative quantities and on the other hand the actual cumulative quantities (see Section 3).

The CQT is logically divided into three parts from left to right:

- 1) The left part structures the CQT line-by-line in assembly lines and part numbers
- 2) The middle part contains general and up to date information of the part numbers
- 3) The right part shows the development of the cumulative ACQ's and TCQ's weekly and (additionally) daily

To create a high ease of use that supports the planner in a maximum way, the following functions were implemented:

- o Coloured visualisation to highlight significant data :
 - Negative differences are red numbers to signal demand deficit
 - Editable fields are blue in the background
- o Hiding of rows and blocks which are not necessary for the planning task
- o Weekly and daily quantities available

5.2 Planning Table

After a description of the planning table user interface the process of plan adaptation will be presented in detail.

5.2.1 Plan Visualization

The planning table visualizes the batches of the users associated assembly lines (AL) in form of a Gantt chart. Batches can be manipulated by different actions to adapt the plan.

Figure 4 shows the planning table. The graphical user interface can be divided into three parts top down.

1) Navigation and action area

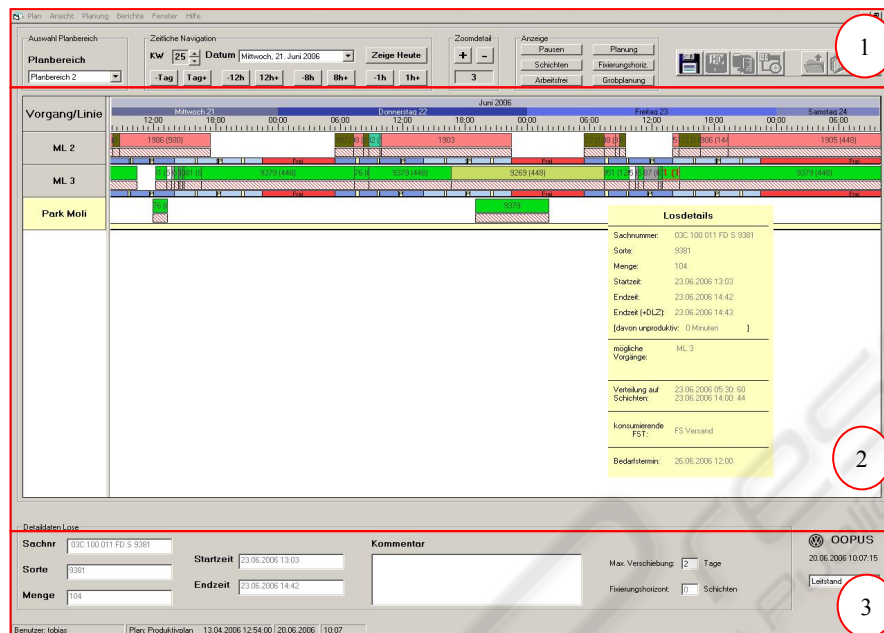


Figure 4: The planning table.

Below the menu bar at the very top is the action and navigation area where the user can navigate in time, change the appearance of the planning table and execute fundamental planning actions.

There are several possibilities to navigate in time and to view the plan in different zoom levels, so the user can adapt the view to his needs. The level of detail can be changed in 10 different levels, from a period of 20 minutes up to a period of 20 days. This gives the user the possibility to look at the plan very closely as well as to get a good overview of the capacity utilization in a bigger time period. To navigate in time the user can scroll the time line in the Gantt chart by drag & drop or by pushing buttons in the navigation and action area. It can directly be moved to a week and a day in this week and at the present point in time. To correspond to the different zoom levels there are different steps to move forwards or backwards in time.

On the right side of this area is a toolbar that includes fundamental planning functions like starting the planning algorithm or saving the current plan.

2) Gantt chart

This is the main area of the planning table where all batches are visualised on the assembly lines and

where the plan can directly be changed by different actions on the batches.

Below each assembly line (e.g. ML 2) there are different visualization elements that provide the planner with information about the shifts that are planned at each time. Blue bars represent productive time intervals, yellow bars break times and red bars signalize that the shift is not productive. Grey bars indicate areas that can not be manipulated by the user (e.g. past the production horizon).

The big bars over the shifts represent batches that are planned to be produced at this time on this assembly line. The batches are divided into two parts. The upper part visualizes the batch itself; the lower part gives information about the batch status and the production progress of this batch. The numbers on the batches indicate their part number and their planned quantities. The colour of the status bar signalizes the status of the batch according to the availability of needed materials. Like a traffic light the colours change from red to yellow and then to green the closer the batch gets to its production start. If the first part of the batch is produced, the status bar gets green and its length decreases to show its progress.

Tooltips are accessible for every visualization element (Figure 4 shows a tooltip for a batch).

3) Information area

At the bottom of the planning table is the information area, where details of the selected batch and the current plan are shown.

In this area important information (e.g. plan has been saved) are shown and feedback to actions (e.g. batch could not be moved to this assembly line) is given.

5.2.2 Plan adaptation

The user can manipulate the plan in three different ways:

- 1) automatic planning
- 2) semi-automatic planning
- 3) manual planning

1) Automatic planning

To create a completely new plan, based on the customer requests and the planned capacities, the user can start the automatic planning algorithm. The result of the algorithm replaces the current productive plan for the current planning area.

2) Semi-automatic planning

OOPUS offers semi-automatic functions to change the current plan. Some of these are:

- Fix the batches that should persist and plan the rest automatically
- Create a batch based on an open demand
- Move a batch to an open demand
- Change the batch size based on an open demand

3) Manual planning

OOPUS offers a very easy and intuitive moving of batches via drag & drop. After a move the batch size is recalculated dynamically by taking both capacities of shifts and included breaks into account. This may lead to a resizing of the batch after a moving action. OOPUS ensures that batches can only be moved to assembly lines where they are allowed to produce and that they do not start or end in areas which are not productive like breaks or weekends.

OOPUS guarantees that there is no overlaying of two batches. If a user moves a batch over an existing batch the two batches are planned in a row without a gap between them. Depending on where the batch was released the batch is planned before or after the one it was released over.

If conflicts occur, for example because the gap is too small or the capacity of the new shift is lower than the one the batch was planned before, gaps with

sufficient capacities are automatically searched and a dialog appears which offers the user to move the batch to the next adequate gap.

The different actions the user can perform to change the plan are:

- Move a batch manually
- Create a new batch
 - based on a chosen start time
 - based on a chosen end time
- Delete one or more batches
- Fix one or more batches
- Move a batch based on open demands
- Change batch size
- Set one or more batches to the status “free for production”
- Set one or more batches to the status “produced”

Because not all of the possible actions can be explained in this text, the planning of a new batch should exemplify the work with OOPUS.

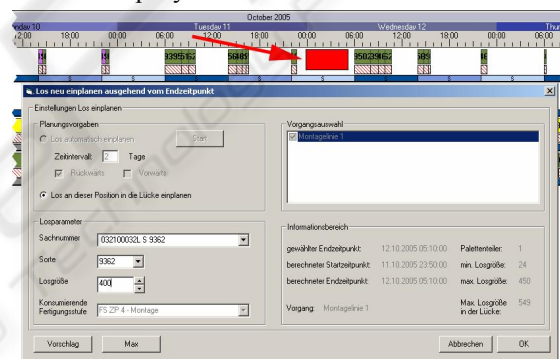


Figure 5: Dialogue to create new batches.

To create a new batch the user has to know the time and the AL where he wants to generate the new batch. After right-clicking at the background at the intended time and AL an menu appears where the user can decide whether he wants to create the new batch with the chosen time as start or as end date.

The combo boxes for the possible parts and sorts are filled dynamically at the start of the dialogue (Figure 5) and contain only the parts which can be produced on the chosen AL. After choosing the part number, information for this part, like the calculated maximum quantity in this gap, are shown on the right side of the dialogue.

If a batch size is entered the beginning and end time of the batch is calculated and a virtual batch is displayed in the Gantt chart.

If the desired batch size is bigger than the capacity of the chosen gap, the user has the possibility to start

an automatic search via the dialogue. For that he can specify in the upper left area of the dialogue if the search for a gap should be done forward or backward or in both directions around a number of days. There is also a decision at which AL's the algorithm should search if there is more than one AL that can produce that part. By pushing the Start-Button the algorithm searches for a gap and proposes one if possible.

The virtual batch will be redrawn whenever the batch parameters changes and becomes the new batch if the user confirms the dialogue.

As shown above the user has many possibilities to adapt the plan according to his preferences. Each action regards the restrictions for the part number as well as the capacities and inactive times to ensure that a current plan is always valid according to the master data.

Additionally the planning table gives the user an overview of the actual production progress by showing batch progresses in real time. Thereby the user can always compare the planned with the actual progress and adapt the plan if necessary.

5.3 Interaction of both interfaces

Using both modules at once offers maximum information transparency to the user. He sees both the calculated cumulative quantities and the batches which these quantities are calculated of. Whenever a change is done in the planning table the CQT is updated, thus the user can see the impacts of his actions immediately. To see both modules at once a dual monitor mode is recommended.

In Figure 6 a semi-automatic function is presented as an example to show the interaction of both modules. Down left in the new batch dialogue (see Figure 5) is a button which offers a proposal based on open demands for the part number in the selected gap. The CQT in Figure 6 shows a deficit of 134 on 2006-11-13.

After pushing the proposal button, OOPUS checks if there is a deficit at the chosen gap and in the case of a deficit checks whether the whole deficit can be planned in the gap or not. If the deficit can be eliminated, a batch with the size of the deficit will be proposed; otherwise the whole gap will be filled to reduce the deficit to a minimum. In this example

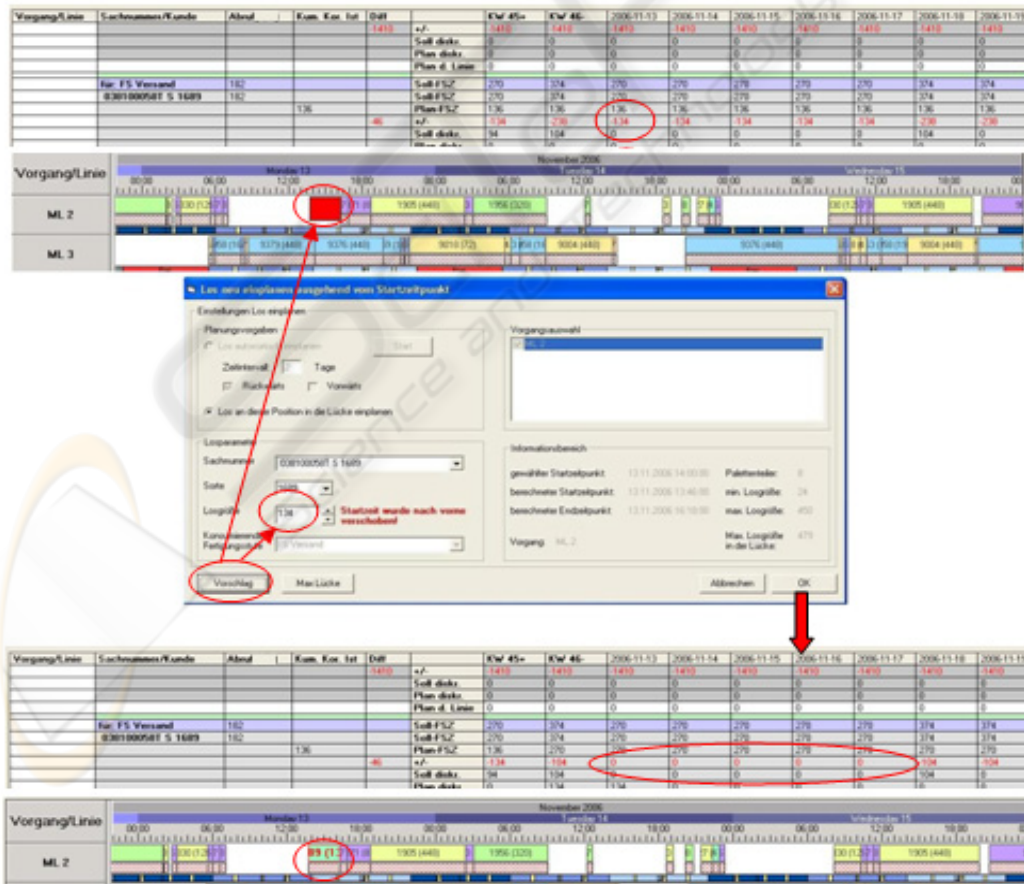


Figure 6: Example of creating a batch semi-automatically.

OOPUS generates a proposal of 134 to eliminate the deficit.

Down in Figure 6 is the result after confirming the proposal. By creating the new batch there are no more deficits for the part number in the time from 2006-11-13 till 2006-11-17.

6 CONCLUSION

The software OOPUS, presented in this paper, is used by an international automobile manufacturer to plan and control his engine production in two manufacturing plants. Thereby OOPUS replaced different isolated applications to unite all aspects needed for the production planning and control in one application. Additionally OOPUS automated many processes which were handled manually and without IT support before.

OOPUS guarantees a higher planning reliability by taking every required data into account to create a production plan that is valid and efficient.

By using two integrated interfaces, the CQT and the planning table, OOPUS guarantees maximum information transparency. The user gets a compressed, but complete overview of all the relevant data he needs to plan and manipulate the production plan. The CQT gives an overview of the situation for the complete planning horizon by comparing cumulative quantities based on customer requests with cumulative quantities based on the already produced parts and the planned parts of the current plan. The planning table shows this plan and offers many actions to change it manually, semi-automatically or automatically. Every change of the plan leads to a recalculation of the CQT, to ensure that both interfaces always show the same updated information.

This maximum information transparency leads to a big saving of time for the production planner who no longer needs to change between different applications to create and control the production plan.

OOPUS was developed based on the specific requirements of an automobile manufacturer, so it is integrated into the system architecture of this customer. This leads to the idea of developing a system called OOPUS-WEB which is a platform independent web application and inherits the main ideas of OOPUS. Therefore OOPUS-WEB can be used by smaller companies as well as being integrated into complex information system infrastructures at large companies.

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