Event-Based Planning for Standard Polymer Products

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In a highly dynamic market environment, naturally the planning situation may change very rapidly by variation of demand and available supply quantities or by sales and procurement price fluctuations. Furthermore, the dynamics of changes may fluctuate over time with intervals of stable conditions followed by more dynamic intervals. Timely consideration of these changes requires frequent updates of plans. A high reactivity nonetheless can be reached with fixed planning cycles only at the very high cost of frequent planning.

An event-based synchronization of demand and supply can ensure the necessary increase of planning quality and limit planning expenses to the necessary minimum. Events are triggered as soon as significant deviations from planning target or deterioration of input data quality are monitored. Thus planning cycles are not started as long as the current plan fulfills all criteria.

This study describes the planning scenario of a chemical industry company which has implemented its mid and short term planning activities in an event-controlled integrated planning system. Decisions regarding demand and master planning are closely linked to production planning and detailed scheduling as well as to sales order confirmation. Priorities upon use of bottleneck resources or limited input material supply are considered throughout all planning levels. Such prioritizations finally determine quotas limiting the confirmations of customer requirements (see Chap. 9).

The case study breaks down into the following parts. First, the planning environment and current market situation of the company are outlined. The solution method of event-based planning is presented next. In the following section, the planning process and its elements are described in more detail. Emphasis is put on the methods of coordination within the planning process and the used planning methods. Benefits of the implementation and major findings gained during project realization are outlined in the last section.

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27.1 Case Description

The chemical company produces a few standard polymer products which are manufactured in different versions. The product is made of crude oil in several refinement stages. It is used in numerous applications for the production of packaging, films, enclosures of electrical appliances, and components for entertainment electronics or household goods. The polymer is manufactured as granulate and then injection-molded or extruded by the customer in the final product. The chemical company produces for the European market at several locations. The various sites preferentially supply selected European countries. In addition, depending on the supply situation, allocation of countries to production sites is also handled dynamically.

The limitation to a few product versions is a response to the development of the market in the direction of a commodity market with standardized products that are produced at high volumes. The individualization of the products, e.g. by dyeing with pigments is increasingly carried out by the final consumer. The flexibility of being able to produce different products has therefore shifted to the final consumer.

The chemical company is facing a highly competitive environment. While it retains an important position in the overall market, its market share is comparable with that of the top competitors. From the customer's viewpoint, polymer manufacturers are easily replaced. The product price is highly dependent on the price trends of crude oil, and other raw materials. The demand is likewise highly sensitive to price revisions. Hence, pricing is an essential marketing instrument of the company. Differentiating features with regard to quality and delivery reliability do not exist as they are taken for granted by the market.

As a rule, price changes of crude oil have an impact on subsequent raw material costs at a very short notice. These cost changes can, however, be passed on to the customer only with a certain time lag. This can result in the shrinking of the obtainable profit margin and in extreme cases even become negative. A possible reaction to this situation is the deliberate reduction of quantities put onto the market. With this measure, quantities which need to be marketed at a negative margin are kept under control without giving up major market shares at the same time.

Falling sales prices subject raw materials and finished product stocks to a very high valuation risk. Stocks produced with highly priced raw materials sold in phases of low sales prices clearly reduce the available profit margin.

To achieve high profitability, it becomes necessary to pay consistent attention to low production costs and to combine this with efficient responsiveness to market prices. Therefore, it is necessary on the one hand to plan resources efficiently, and on the other hand to forecast market changes as well as possible, and to incorporate them into planning with little delay. The entire supply chain should be coordinated with the highest possible degree of integration. Not only individual components such as allocating production quantities to different production sites must be carried out but also be combined with other planning steps such as defining production sequences and planned output as well as the distribution of production quantities

to the different markets. Planning must be linked closely to the various business functions, such as procurement, demand and production planning which must be coordinated with little time lags.

These requirements can be met by a system which demonstrates both a high degree of integration and a rapid response to changes in the planning conditions.

27.2 Solution Concept

At project begin, demand and master planning were realized as harmonized processes implemented in a unified system base. This solution was based on the module Demand Planning (DP) of SAP SCM and is being used for the demand planning of all markets and products of the business unit in question (see Chap. 7). This allows achieving a high level of transparency on the requirements of all markets and keeps good track of any changes from sales forecasts. The forecasts and their manual reviews are undertaken at fixed dates. The planning cycle is completed once a month and provides the required input data for subsequent master planning (see Chap. 8). A response to unusual market changes with subsequent adjusted master planning is made only effective to the next planning cycle.

So far this planning platform has ensured consistent planning with only minor data errors. However, in view of the high degree of change in sales, the reactivity of the planning system was not high enough and resulted in lost sales and excessive inventories of finished goods, depending on the current demand situation.

This initial solution concept has now being expanded towards increased reactivity. The fixed planning cycles have been discontinued so that now planning can be undertaken at any point of time, i.e. event-based. This imposes two conditions: on the one hand, there must be a continuous data supply and updating; on the other hand, deviations from the plan must be continuously monitored. Monitoring is essential since it determines the need to start the following planning cycle. By including the inventory days of supply and production capabilities, changes to both the sales market and the supply side of the supply chain can be monitored.

As soon as predefined thresholds are exceeded, a separate demand or master planning or, in the case of major deviations, total replanning of sales and the production network is triggered. Typically, the planning frequency is higher than it is for planning in fixed planning cycles since demand planning can be carried out separately from master planning and no complete replanning is required in every case. At times of fewer changes or deviations, the planning frequency may be reduced.

Closely connected with planning is the implementation of plan-based decisions. A system-supported implementation of current planning results is necessary, in particular with frequent and non-synchronized changes. This is done by integrating the availability check at the time of order entry (see Chap. 9) with the results of detailed production planning. For this purpose, planned production quantities are returned to demand planning, and considering actual sales forecasts, a quota allocation of available stocks and planned receipt quantities of final products

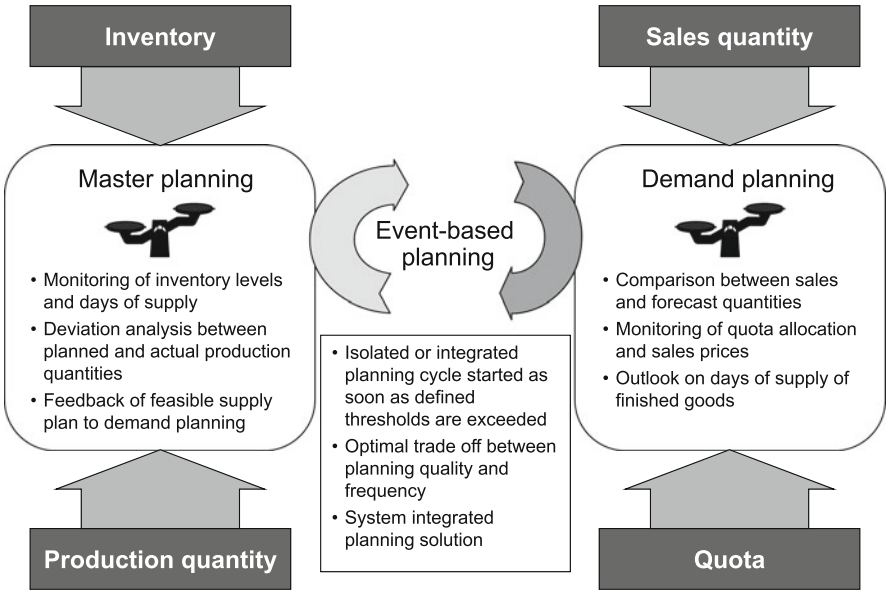

Fig. 27.1 Event-based planning in demand planning and master planning

for the various markets is undertaken. When orders are entered, final product availability is confirmed only if the quota for the market to which the customer is assigned is not yet exhausted. Consumed quotas are employed to monitor market conduct and may result in triggering a new planning round whenever a quota is used up. The decision is taken in due consideration of the current supply strategy so that a deliberately generated scarcity of the supply and the resulting early exhaustion of available quotas does not trigger new planning.

Figure 27.1 shows the two planning areas of demand planning and master planning. A new planning is triggered when the data to which the units are linked display clear deviations from expected values. In the event of major deviations between these indicators, the system issues alerts for the planner. Depending on the degree of discrepancy, replanning is initiated only within the area or a new coordination of both areas is launched.

When monitoring demand planning processes, the following performance indicators are used:

- Deviations of customer orders from the forecast
- Deviation of selling prices from plan prices
- Consumption of quotas through customer orders.

These performance indicators basically deal with the question whether the demand deviates from the plan. In the case of larger deviations, new planning is made initially within the demand planning process. Thus, e.g. the plan for a region can be overruled if the customer quota shows an excessively high degree

of consumption. If the stocks of that product are still sufficiently high, matching the quota could be sufficient without having to trigger a new production planning.

The monitoring of the master planning involves the following performance indicators:

- Inventory days of supply of final products
- Finished production quantities to planned production quantities
- Resource utilization.

If the inventory days of supply fall below the specified target value, it will be necessary to modify the production quantities or dates. With smaller deviations, manual corrections on selected products may be sufficient, but with larger deviations new planning for all products or production plants will become necessary.

Thresholds on the performance indicators in demand and master planning have been defined along with aligned measures. Measures state whether separate planning of an individual unit is sufficient or whether the replanning of the entire supply chain planning is definitely required. In this way, a balance between demand and master planning is created.

27.3 Planning Process

The planning process not only covers activities for demand and master planning, it also aligns short term planning decisions to the master plan. Short term production planning, management of sales order quotas and its integration into the sales order availability check are the subsequent planning steps.

Figure 27.2 shows the planning levels in detail. The various elements are described more closely in the following sections.

27.3.1 Demand Planning

The determination of future sales quantities starts out from the historical sales figures which are used as a basis for a statistical forecast (see Chap. 29). The customer orders are initially stored in a central SAP Business Information Warehouse (BW) and the sales figures consolidated there are then transferred to the BW which is integrated into Demand Planning (DP). Sales figures are updated daily in the DP and the statistical forecast is also carried out daily.

A monthly rolling sales quantity plan (business forecast) for the business unit is defined with respect to the sales goals for the current year. A consolidation is carried out between logistics, production management considering production capabilities, product marketing, and regional sales management. The business forecast is the framework for required production capabilities and the achievable sales quantities in the different markets.

The sales quantity plan is created in a detailed way for the next 3 months with an extension for the months 4 through 6. This plan is created at the product group

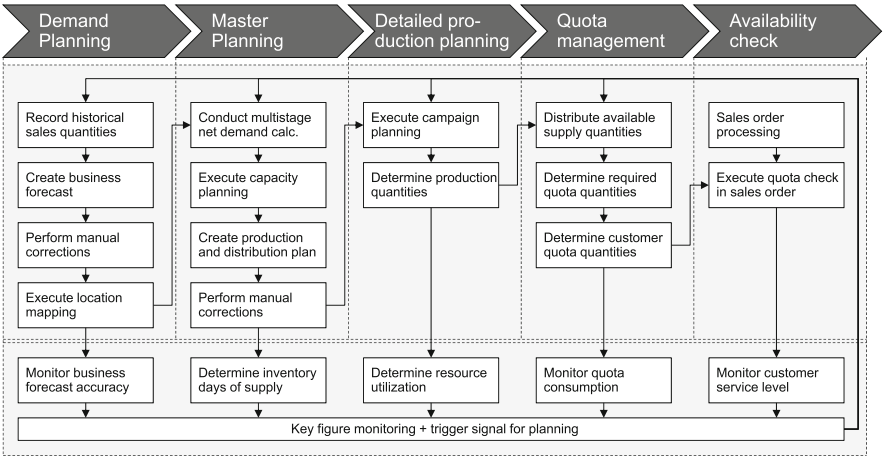

Fig. 27.2 Detailed flowchart of event-based planning

and sales region level. The sales quantities may be refined manually to correct the figures of individual products or countries.

The regions are preferentially supplied by certain production sites. Thus, the next step is location mapping which assigns by region which production site is to supply a given demand. It is still possible to deviate from this allocation during master planning; however, the additional shipping costs are weighed against the overall goals pursued by planning.

As a last planning step, the external sales quantities are reviewed a last time and are released by sales planning to master planning.

The sales quantities are monitored in the quota management. The actual sales quantities are compared to the defined quotas. In case of significant deviations, quotas may be updated or in case of major deviations a trigger for the update of the sales quantity plan may be given.

27.3.2 Master Planning

Master planning is carried out with the help of SAP SCM module Supply Network Planning (SNP). The goal of this planning step is the definition of a production and distribution plan which covers all external demand while considering relevant production and distribution constraints.

For this purpose, various planning tables for manual adjustments as well as the SAP (standard) optimizer for automatic planning runs are used. Planning is done for the next 6 months using a detailed monthly breakdown. Accordingly, monthly buckets are used to define the monthly quantities to be produced, procured and redistributed.

First, all demand types, receipts and stocks are consolidated in the net demand calculation. For this purpose, a SNP planning table is used in which total demand, both unfulfilled customer orders and the consolidated gross forecasts carried over from demand planning, is shown. In addition, currently available raw material quantities as well as redistributions within the production network and redistributions to other company departments are shown. Already at this level, the planner can enter requirements for the automatic master planning run, e.g. by correcting available raw material quantities. This step may be repeated several times after the first results of the automatic planning run are available.

The automatic planning run performs several steps simultaneously. Thus, the calculation of dependent demand, the capacity planning as well as the drafting of a production and distribution plan in a single planning run is made, invisibly to the planner.

The planning run uses a cost-oriented mathematical optimization method (SAP Standard) which aims at minimizing all decision-relevant costs. The planning run is controlled by modifying the cost parameters and by weighting partial goals. For example, the storage costs at the various stages of the distribution network are quoted for every product. Warehousing can be controlled through the different cost rates at the various locations so that e.g. at a high warehousing cost at the production site and at a low cost at the distribution site, stocks are redirected to the distribution warehouse. By weighting partial goals it becomes possible to set priorities so that e.g. warehousing costs can be put into a relationship to the costs for late delivery.

The optimization run of the automatic master planning takes into account the following costs whereby the overall goal is to minimize total costs:

- Production costs
- Storage costs
- Transportation costs
- Costs for violation of the safety stock level
- Non-delivery costs
- Late delivery costs.

The costs are set as a function of the site (e.g. site-specific transportation costs) and of product (e.g. non-delivery costs) and/or as a function of both the product and the site (e.g. production costs, location specific storage costs).

Next to these goals, the optimization run is also controlled by further input values. These take into account on the one hand the constraints to be respected, such as discontinuations, and capacity profiles but also planning decisions already made such as fixed production quantities or minimum resource utilizations. Other production and procurement relevant limitations are minimum batch sizes for the production of a product and maximum purchasing quantities.

The plan, created by the automatic planning run, is a proposal to the planner which can be revised in the SNP planning table. Thus, he can e.g. increase the production quantity of one product at the expense of another if the prioritization of products by production costs has been insufficient. The monthly production and distribution quantities then become the requirements of master planning which must

be incorporated into the subsequent detailed production planning. In each case only the current month and the next 2 months are supplied since this is the limit of detailed production planning.

27.3.3 Detailed Production Planning

The detailed production planning is performed using an independent optimization solution using IBM ILOG CPLEX Optimizer integrated into the SAP system. The PP/DS module installed in the SAP standard cannot be used for these tasks since there are special requirements not covered by the standard:

- In many areas the resource output rate is variable and is a planning result.
- The outputs of several production stages must be coordinated with each other in such a way that no intermediate stocks are generated.
- During product changes, set-up times apply while production continues so that the resulting product is, however, outside the specifications; plus there are further specific requirements.

The master data in SAP SCM provide that a resource is working at a fixed output rate but different (constant) output rates can be defined. Planning procedures do not allow the definition of continuous values for the output rate. Accordingly, the planner is unable to easily and efficiently set the individual resource output rate for each order.

In the production process, several stages are directly linked to each other so that no storage of intermediate product is possible. An aggravating factor for planning is that the resource output rate on the different production stages can change and that these changes need to be reflected into the output rates of adjacent stages. In the module PP/DS of SAP this is only partially supported by the automatic planning procedure.

In detail, the production process must meet various requirements which can be modeled in the SAP standard in part. Thus, e.g. a resource can only be used for production or it is performing a changeover activity, both cannot be modeled in the SAP standard at the same time. The raw material consumption arising during a changeover is, however, not negligible and must also be considered; one reason being material flow must not be interrupted on intermediate production stages.

To be able to overcome the above-mentioned limitations of the standard, a specific optimization solution which includes a separate user interface was created to allow easy modifications of output rates.

Detailed production planning and scheduling determines the daily production quantity for products on the resources of the sites based on the monthly requirements. Planning is performed for the current month as well as the next 2 months.

The main goals of detailed production planning are:

- The monthly input quantities computed by SNP must be met as accurately as possible.
- The target inventory days of supply of the products is to be met as accurately as possible.
- Changeover times are to be minimized.

Detailed production planning must solve the following essential tasks and respect several constraints:

- A resource can be used only to manufacture one product at the same time, within 1 day there may be at most one changeover, i.e. at most two products can be manufactured per day.
- The preferred production sites should be respected when products are manufactured by multi-sourcing.
- For each resource, an optimal output rate is specified which should be reached if possible; the output may vary between a minimum and a maximum.
- Only a previously defined limited number of product changes and output rate changes are allowed per day, production site and group of resources. Sometimes such changes are allowed only on certain days.
- During a product changeover a very specific changeover time applies per resource, product outside the specifications is produced, and raw materials are, however, consumed.
- Continuous production on all production stages, no resource standstill (except in the case of discontinuations).
- No stocks between production stages, only at the level of raw materials and finished products.
- After a discontinuation, a resource must be started up at a predefined pattern, only certain products are permitted for the first order.
- Raw materials are available only in a limited quantity.
- Production campaigns have a predefined minimum length.
- The products are produced preferably on certain resources, however, changes to another resource are allowed.
- Fixed orders must be taken into account and cannot be modified.
- A certain portion of waste and products outside specifications can be returned to production as raw material.

The optimization task is solved using a multistage mixed-integer optimization model. The model is decomposed into separate parts and solved in consecutive steps. The first step is an allocation of orders to resources and determination of the sequence of orders on the resources. The second step is the definition of order sizes as well as output rates of resources and definition of changeovers.

A checker is available to ensure that manually corrected plans observe all the constraints of the planning task. This is an especially adjusted optimization model which loads a predetermined planning situation and records all violations of constraints in a log file. From this log file, the planner can see both, the detailed figures of partial goals and the degree of non-compliance by soft constraints and possible violations of hard constraints. Figure 27.3 shows the architecture of the detailed production planning solution.

Detailed production planning is started by the planner in the APO after master planning has been completed. Next, the optimization user interface is loaded in the planner's workstation. From this interface, similar to the graphical planning table in SAP SCM, he can control the entire planning process. He can look at the existing

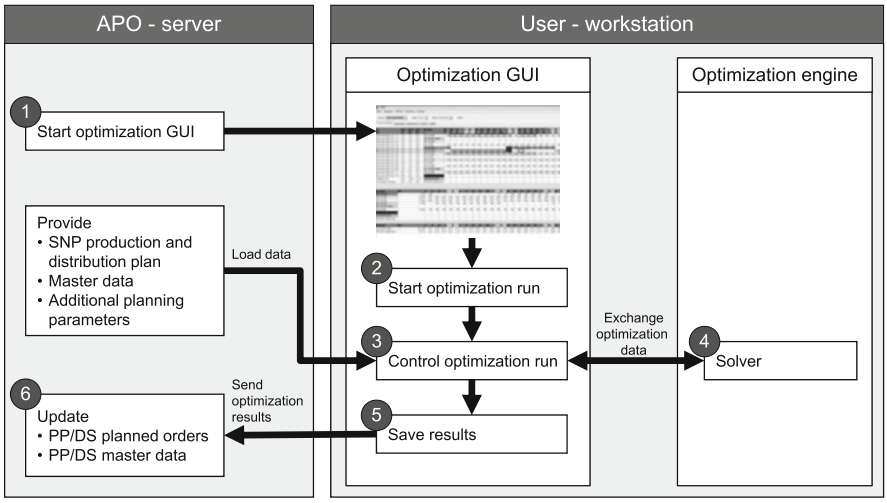

Fig. 27.3 Architecture of detailed production planning solution

order situation, modify the constraints for optimization, trigger an optimization and manually correct optimization results.

After the start of the optimization, all relevant data is loaded from the APO. This includes the input data from the SNP for the monthly production quantities as well as the master data, e.g. the recipes and routings. In addition, settings not available in the SAP standard such as minimum and maximum output rates of resources are transferred. The data is then processed and transformed into the data model of the solver. The various subsequent optimization steps are executed and results exchanged between the solver and the optimization GUI.

After optimization is completed, the planner can verify the results on the interface and if necessary, adjust them manually. Possible changes are adjusting the output rate of resources, the production length of a campaign or defining on which resource a product is to be produced. When the planner is satisfied with the result, he stores it and starts the return transfer to the APO. In the APO, the necessary changes to the master data are automatically carried out to permit new output rates on a resource. Thereafter, planned orders are generated.

Production planning and scheduling is completely modeled with SAP standard objects so that it can be processed further in the subsequent SAP standard process. The generation of process orders for production is then again made entirely in the SAP standard.

27.3.4 Quota Management and Availability Check

Production quantities defined in detailed production planning are used to generate the quotas which must be available to satisfy customer demand per product and region. For this purpose, the production quantities are returned to demand planning. The demands of the regions, and the available stocks and the production quantities are then shown by product. These are compared to the planned sales quantities. If the available quantities are adequate, the quotas can be allocated as required by the demand. Otherwise, the quota planner reduces the amount of the quota to available quantities in regions which cannot be fully supplied (see Fig. 9.5).

Quotas are communicated to sales management, which may accept, increase or decrease them. The desired quotas as defined by the sales management are taken into account by the quota planner. He will then reallocate the quotas accordingly. As an option, sales management may define additional customer specific quotas within a region.

When a customer order file is created, an availability check is always triggered in order to check whether the product for the customer order is available. This is done by checking existing stocks but also planned receipts. In addition, the order quantities are checked first against the quota of the region to which the customer is allocated and second against the customer specific quota if one has been defined.

With every confirmed customer order, the available quota is reduced by the order quantity. A customer order cannot be confirmed without a free quota; this implies that the total of all customer orders within a region may not exceed the quota quantity or available quantities.

The consumption of the quota is monitored by the quota planner continuously and its consumption may lead to a redefinition of the regional quota. This update is communicated to the sales management and afterwards the described coordination takes place. In case of significant deviations, it may be necessary to update the sales quantities in the demand planning. The quotas will then be redefined based on these new sales quantities.

If the available quota is exhausted; the customer order can no longer be confirmed. Where special priorities exist, the customer order can be confirmed after an increase of the quota. When there are no priorities, the customer order is declined and then transferred to backlog processing.

27.3.5 Key Figure Monitoring

New planning of individual parts or throughout the entire planning solution is triggered whenever there are major deviations between the expectations of future and actual development. For this purpose, various key figures are monitored, see Sect. 27.2. The monitoring is done in parallel to the planning steps in demand or production planning.

Key figures are evaluated in a daily review cycle. The signal for a new planning event is given if the threshold of the key figure deviation is exceeded.

The planning does not start automatically. The responsible supply chain planner evaluates the situation and decides upon the start of the planning. While the main basis for the decision should be the planning signal, he may delay the planning for some days or increase the scope of the planning, e.g. start demand planning in all regions, not only in the region where the planning signal was triggered.

27.4 Results and Lessons Learned

With the above-described process, the company was able to substantially increase its responsiveness to changes in the market and in production.

The key factors here are close integration and the coordination of partial processes, and the standardization of processes. The labor-intensive coordination and data transfers could be avoided and planning results are obtained in a short time, and new planning results implemented with little efforts. Moreover, significant influence comes from a well adapted planning process and from an extensive coverage of functional requirements.

By recognizing the need for new planning event, the necessary corrections can be directly triggered without having to accept a long delay up to the following scheduled planning round. Now a completely new planning solution can be obtained within a couple of days. An isolated update of i.e. the network and the detailed production plan can be derived within less than one working day. The efforts to create a new planning solution are significantly lower.

Main benefits were achieved by improvement of the following key performance indicators.

- Significant increase of on time deliveries
- Reduced number of days of supply of finished goods
- Reduction of production costs.

Lost sales in case of increased customer demand were reduced significantly. Excess stock of finished products is avoided completely as the production quantities are synchronized very closely to the market demand. Improved coordination of the production sites increased reactivity to short term demand variations.

The implementation of the planning solution helped the company to improve the organization of the planning department. The benefits were achieved through stable and coordinated processes of planning and execution.