22 Scheduling of Synthetic Granulate

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This case study deals with a project which has been finished in its first version in the process industry in 2000 with a quite early release of APO PP/DS and which has been further improved by new releases of SAP APO with their additional functions and the integration of more parts of the supply chain. It was the first APO PP/DS project that managed to keep up with the difficult scheduling requirements in the field of the chemical and process industries.

This case study is structured in the following sections: First, the general production process of the synthetic granulate in the featured plant is presented. This chapter focuses on the special planning problems which occurred in this example. Subsequently, the modeling of the production process in APO PP/DS is described in detail, and some more information about modeling production processes in APO PP/DS are provided in addition to the general information given in Chap. 10 as well as a short view to the planning process. At the end of this case study the results of this APO implementation are estimated briefly as they could be measured today and the lessons learned are presented.

22.1 Case Description

The production process dealt with in this case study is the production of synthetic granulate. In technical terms it is a four step hybrid-flow-shop production process. The granulate is widely used in many different industries, especially in the automobile and pharmaceutical industries. About 3,000 different products make up the full product spectrum which grows and changes rapidly.

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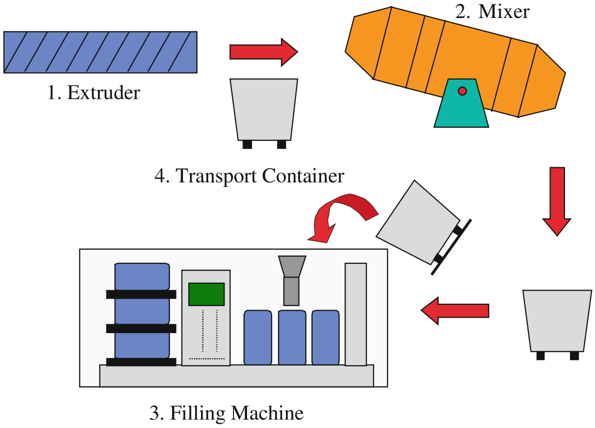

Fig. 22.1 Production process

The basic principle of the process (see Fig. 22.1) is melting the undyed granulate in extruders, adding color substances and perhaps other additives and extruding the colored granulate again. Depending on the product type, a mixer is used afterwards to create homogenous batches. If the granulate is shipped in bags, an automatic bag filling machine may be used. Otherwise the filling of the granulate in different types of containers is done directly at the extruders or mixer. Depending on the production sequence, transport containers may be needed during a part of the production process. At the end of the production process some more days are needed for the necessary quality checks.

The selection of resources for the production process depends on the product type. For the extrusion process several individual extruders can be used. These resources differ with respect to speed, types of color that can be added and types of undyed granulate that can be processed. The actual usage of the individual extruder depends on the product type and the lot-size of the production order. Generally speaking, for each product there are several extruders with different priorities that can be used for the extrusion process. As there is a high variety of products with very different chemical and physical characteristics, the scheduling of orders on the extruders is very critical. Depending on the sequence of the production orders, setup times for cleaning the extruders vary between nearly no setup time and up to 5 h.

Products with special quality requirements by the customer have to be mixed afterwards to create batches with homogeneous characteristics. For this part of the production process several mixers with different capacities are available. The selection of the mixer is lot-size dependent. Also the setup times on the mixers depend on the sequence of production orders, but the scheduling is less critical, as the setup times are shorter and the mixer is usually not a bottleneck. Granulates which are shipped in bags can be packed in two different ways. The first alternative is packing directly at the extruder or mixer which requires no additional resources. This procedure is chosen for production orders with small lot-sizes. Large production orders are packed with a special automatic filling machine which has to be planned separately. The setup times are sequence dependent as well, but less problematic than setup times on extruders. A further resource group, the transport containers, is needed, if a product needs the mixer or the filling machine or both of them. As the automatic filling in bags does not take place directly at the extruder, the transport containers are used to transport the loose granulate from extruder to mixer and further on to the filling machine. Since the number of available transport containers is limited, they must be considered as a relevant resource. The last resource group is the personnel required to operate the machines. Several different qualification groups can be distinguished, all of them have to be considered for production planning. If several workers are not present, use of certain machines might not be possible and production must be rescheduled.

22.2 Objectives

As mentioned before, the sequencing of production orders is the critical task in the planning process to avoid setup times and costs. An ideal sequence of production orders regarding the setup times would be a sequence starting with a very bright color (e.g. yellow) and ending with a very dark color like brown or black. This sequence leads to no setup times between the orders (as there is no cleaning necessary when changing from bright do dark) and in a long setup/cleaning activity at the end of this "campaign". This setup optimization task and the fact that many different resource combinations for the products must be considered makes it hard for the production planner to generate feasible and economical plans in a short period of time. Especially the setup problems usually have been solved by building large standardized campaigns of similar products. Moreover, the plans once generated could not be changed easily when machines broke down or special short-term orders had to be fulfilled. This situation has been tackled by allowing buffer times in the production schedule. If this buffer time was not needed, the production capacities were not exploited to their maximum. So there has been the clear demand for an intelligent production planning and scheduling solution. This and as the integration with SAP R/3 should be as seamless as possible led to the decision to implement SAP's *Advanced Planner and Optimizer (APO)*.

22.3 Modeling the Production Process in APO PP/DS

Within this section of the case study not only the actual modeling of the production process in APO is described, but also some general principles of modeling processes in APO for production planning and scheduling in addition to the general description in Chap. 10. When this project was introduced for the first time, APO release 2.0 was the most current release. Although we are talking about mySAP SCM release 7.0 today, the basic principles of modeling supply chains in APO are still the same. Also the presented case has already undergone some release changes but still works in the original configuration and model. Of course, not all options of modeling with APO can be presented here.

22.3.1 General

In Chap. 10, the groups of data needed for planning have been defined. Especially the necessary master data will be explained in this chapter.

To use the PP/DS module of APO for planning and scheduling in industry, basically the following groups of master data must be maintained in the system:

- Locations
- Products or parts
- Resources
- Production Process Models (PPMs)
- Setup matrices
- Supply chain models.

Additionally, transactional data (e.g. sales orders, planned orders, inventories and setup states of resources) will be needed for planning. As the APO is using a standard R/3 basis system to maintain the system functionality, it uses a relational database of its own to maintain master and transactional data. Therefore, data are not handed over using flat ASCII files which are read by the system on start unlike most other advanced planning systems. Considering this, some information about filling the system with data will be provided:

Usually, a special interface provided by SAP will be used to connect the APO system to an R/3 system (APO Core Interface, a part of the R/3 PlugIn). This interface generates the master data by an initial upload and communicates the transactional data as soon as they are changed by one of the systems. This guarantees the fastest and most recent data transmission. Nevertheless, other interfaces to non-R/3-systems may be used as well.

22.3.2 Locations

The *location* is the first step, when creating a model. As APO is an integrated supply chain planning tool, it is important that all the subsequent data can be assigned to individual locations. Although for the *supply network planning* there are several kinds of locations (supplier, production plant, distribution center, customer, transportation zone, MRP area, transportation service provider and terminal), for the PP/DS only the production plants are relevant. This makes up one location—a production plant—for this production process. This data object corresponds with the organizational R/3 data object "plant" and is transferred using the standard Core Interface.

22.3.3 Products

For every product which is to be planned in APO (final product or raw material) a set of *product master data* has to be generated. The APO philosophy for the selection of the "relevant" products suggests that only critical materials should be planned in APO. So, one will usually plan the final products and some of their critical components in the APO system. Thus, only a portion of the materials contained in the complete bill of materials (BOM) is transferred to APO. In this particular case, the final products—the colored granulate—and the undyed granulate are planned in APO, although the BOMs in R/3 contain many additional components like some additives. But these are no critical components and are not planned in APO. The complete BOM is exploded in R/3 and the additional components are generated as secondary demands, when a generated or changed order is retransmitted to the ERP system.

A lot of the settings and product properties are not relevant for PP/DS planning and are not presented here. The important values for PP/DS are

- Basic unit of measurement
- Alternative unit of measurement
- Lot-size calculation
- Planning method
- Procurement method.

The *units of measurement* are taken over automatically from the R/3 system, depending on the product. It is usually "unit" or "kg" for this production process. Regarding the *lot-size calculation* APO offers the following options: fixed lot-size, lot for lot with a maximum/minimum lot-size and lot-for-lot without maximum/minimum lot-size. For the lot-for-lot calculation a rounding value can be defined. In our case, all the products use lot-for-lot with maximum/minimum lot-size. All these individual values are taken from the R/3 system.

The *planning method* describes how APO will react, when a demand is transferred. If the planning method is "automatic planning", the system checks the availability and—if the check is negative—creates a planned order or a purchase proposal (depending on the procurement method). If "manual planning with check" is selected, the system checks the availability and creates an alert in the *Alert Monitor*, if the check is negative. But it creates no orders of any kind. The third alternative "manual planning without check" always assumes that there is enough material to fulfill the demand. The *procurement method* determines, what APO will do if a demand cannot be fulfilled using stored materials. The procurement method offers the settings "in-house production", "external procurement" or "in-house production or external procurement". The last option is "direct procurement from other plants".

When "in-house production" is selected, the system creates a planned order for the product, considering resource capacity availability and material availability simultaneously. When "external procurement" is selected, the system creates a purchase proposal. In case of "in-house production or external procurement" the

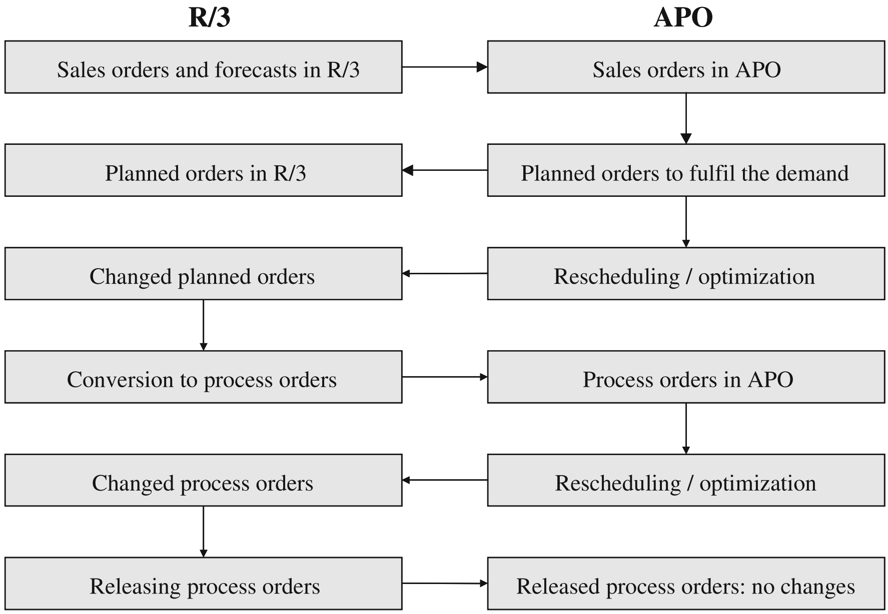

Fig. 22.2 Planning process using APO and R/3

cheaper alternative is selected, so costs for production and external procurement have to be maintained.

The planning method "automatic planning" and the procurement method "in-house production" have been selected for colored granulates (the final products) in the first version of this case. So, automatically planned orders were created and sent back to R/3 immediately, if a sales order cannot be fulfilled using stored materials or work-in-process. The undyed granulate status was set to "manual planning with check". So, if there was not enough material for production, a warning in the Alert Monitor has been created. The reason for this was that the undyed granulate production which takes place in another plant of the same company was not yet integrated in the PP/DS planning process. As soon as this integration was completed, it was possible to check the availability of the corresponding undyed granulate and create a planned order for it immediately in the other plant together with a transportation order to the plant, where the colored granulate is produced. As soon as this second plant was integrated into SAP APO a common planning process was established using a APO PP/DS planning heuristic working with finite capacities ("finite MRP") to substitute the conventional MRP run in R/3. The automatic planning functionality proved to cause too many changes in the production schedule. Figure 22.2 shows the actual planning process and communication between APO and the ERP system.

22.3.4 Resources

APO uses several different types of *resources* for different planning requirements. For PP/DS *single* or *multi-activity resources* are used. Planning on these resources is not based on periods. They use a continuous time stream, and orders are scheduled using seconds as time units.

Single-activity resources always have the capacity of 1 without any unit of measurement. They represent a machine that can only process one order at the same time. Multi-activity resources are used to model either groups of identical machines which lead to a capacity of more than 1 without a dimension or single machines which can process more than one order at the same time and every order requires a certain amount of capacity. For example, an oven can have a capacity of $10\,\mathrm{m}^3$, and every order processed in the oven at the same time requires some volume of the oven. Several orders can be processed in the oven at the same time as long as the sum of their individual capacity requirements does not exceed $10\,\mathrm{m}^3$.

Not only different capacity types can be distinguished in APO, also the *usage* of a resource is indicated. The resource types “production”, “transportation”, “storage” and “handling” are possible, but only the production resource is relevant for PP/DS.

Capacities can be defined in multiple variants in APO. In this way one can model different capacities for e.g. different shifts or reduced capacities for breakdown times. Besides the amount of capacity there is the possibility to indicate, when the capacity of a resource can be used. While the *factory calendar* describes on which days the resource can be used or not because of e.g. weekends, holidays etc., the *resource calendar* describes the working times for the working days. So, for the working days, the start time and end time of resource availability are specified. Additionally the resource usage can be defined to allow buffer times or reserve capacity for some reasons. This resource usage is measured in percent. Further settings concerning properties of resources can allow some overlap of orders without creating an alert. For each resource a flag can be set whether the actual capacity load should be considered during scheduling (“*finite planning*”) while another flag indicates whether the resource is a *bottleneck*. If the bottleneck flag is set, the system schedules an order first on the bottleneck resource and then the other activities of this order on the other (non-bottleneck) resources. To model sequence dependent setup times, a *setup matrix* must be created and assigned to the resources where these setup times occur. The setup times automatically reduce the resources’ capacity.

The setup times and costs are the only relevant factors to build lots on the resource and activity level as it is done in PP/DS. When using the optimizing algorithms to reschedule an initial plan, activities are planned on the resources in an order which creates the fewest losses by setup times and costs while concerning lateness, production costs and makespan simultaneously.

The classic lot-sizing which regards the trade-off between setup, transportation and storage costs has to be done in the mid-term planning, using the *Supply Network Planning*.

Table 22.1 Modeling the resources

Name	Type	Start	End	Usage (%)	Matrix	Bottleneck	Finite	Capacity	Unit
PERS_1	Multi	00:00:00	24:00:00	90			X	0–2	
...	...	...	...	...	...	...	...	...	...
PERS_N	Multi	00:00:00	24:00:00	90			X	0–12	
FILLING	Single	00:00:00	24:00:00	90	SHORT		X	1	
MIXER_1	Single	00:00:00	24:00:00	90	SHORT		X	1	
...	...	...	...	...	...	...	...	...	...
MIXER_M	Single	00:00:00	24:00:00	90	SHORT		X	1	
EXTRUDER_1	Single	00:00:00	24:00:00	90	LONG	X	X	1	
...	...	...	...	...	...	...	...	...	...
EXTRUDER_O	Single	00:00:00	24:00:00	90	LONG	X	X	1	
QUALITY	Single	06:00:00	16:00:00	100				1	
TRANSPORT	Multi	00:00:00	24:00:00	90			X	30–40	

For the granulate production process, the following resources have been created in the APO system:

- A single-activity resource for each extruder
- Three multi-activity resources for the three personnel groups
- One single-activity resource for the filling machine
- One single-activity resource for each mixer
- One multi-activity resource for the transport containers.

The extruders have been marked as bottleneck resources. So the system first schedules the extruders, as there is the biggest planning problem. All the resources, except the quality testing, are available for 24 h on work days, the quality testing department works for 10 h. Although the quality testing is in fact just a dummy resource—there is no finite planning—the exact working times are necessary to model that the quality testing takes 3 days. Quality testing always starts at the beginning of a shift (6 a.m.) and ends always at the end of a shift (4 p.m.). The use of a dummy resource is necessary in APO, as waiting times without a resource cannot be modeled. If a resource shows a variable capacity, an additional capacity can be defined for each shift to represent the actual number of available workers or transport containers. If no specific capacity is given for a shift, the standard capacity for that resource will be used.

The following Table 22.1 shows the individual resource properties, i.e. the detailed definition of the resources. In fact there are some more fields which can be used in APO, but only the essential ones are described here.

For the synthetic granulate process two setup matrices (SHORT and LONG) have been defined. They both contain the same setup keys, but different setup times for the individual product combination. The matrix with the longer setup times is assigned to the extruders, the one with the shorter setup times to the mixers and the filling machine. The matrix with the shorter entries can be regarded as a copy of the first matrix with all entries divided by a constant factor. The huge number of products can be reduced for the setup matrices as a product in different shipment containers is represented by individual product numbers. The actual setup matrices contain about 2,000,000 entries each. The generation of the setup matrices could not be handled manually, so a special ABAP/4 program in APO generates the setup times, using physical and chemical characteristics of the products (a non-standard functionality).

22.3.5 Production Process Models

The *Production Process Model (PPM)* is the most essential element of an APO model. As presented in Chap. 10, it represents both the routing and the BOMs. So, here it is determined which resources are used for what time and which components enter or leave the production process. This is indicated at activity level. So the production step, when a component is needed or ready, is described precisely. Also the temporal relations between single production steps are defined. APO is the first APS which actually uses the complete PPM concept, while most other systems work with separated routings and BOMs.

According to Chap. 10, a PPM is a hierarchical structure of elements which together form the production process. The elements of a PPM are:

- *Operations* which describe a group of production steps which take place on the same resource without interruption by other production orders
- *Activities* as the single steps of an operation, e.g. setup, production, wait, tear down
- *Activity relationships* which determine the sequence of the activities and their relative position in time
- *Modes* which describe the resource or the alternative resources an activity can use and their duration
- *Capacity requirements* for the primary and secondary resources of each mode
- *Logical components* which serve as containers for groups of physical products (inputs or outputs) and are attached to activities
- *Physical components* which describe the groups of real products represented by the logical components
- The list of products which can be produced using this PPM (which may be all or just a part of the output components) and the lot-size ranges for which the PPM is valid.

As mentioned at the beginning in the description of the production process, many different routings through the process exist depending on the product. Here is presented the "maximum" PPM for a product which uses the extruder, the mixer, the filling machine, the transport containers and several personnel resources. First, the general modeling possibilities and principles for the elements of a PPM are presented, immediately after each element. A practical example is given by showing how the synthetic granulate process was modeled in this step.

For every production step which takes place on another resource an *operation* is defined, as long as this resource is not only needed as a *secondary resource*, parallel to the primary resource (e.g. a worker who is needed to operate the machine). If sequence dependent setup times shall be used, the *setup key* which identifies the manufactured product in the setup matrix is specified in the operation. As there

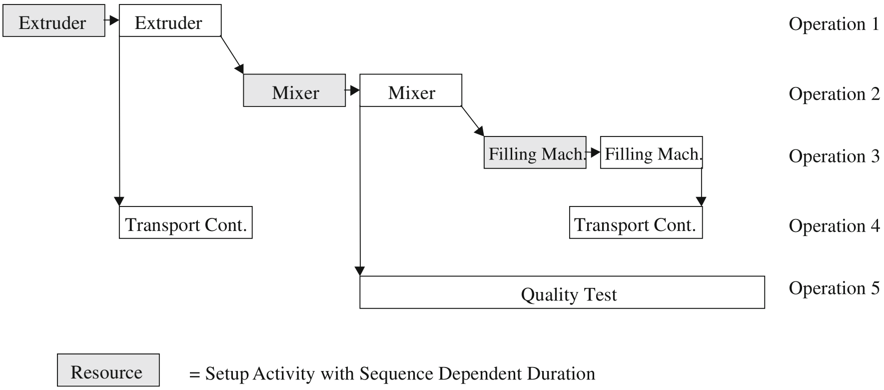

Fig. 22.3 PPM structure of the production process

Table 22.2 Modeling the operations

Operation key	Description	Setup key	Location
0010	Extruder	SETUP_KEY	GRANULATE_PLANT
0030	Mixer	SETUP_KEY	GRANULATE_PLANT
0050	Filling machine	SETUP_KEY	GRANULATE_PLANT
0070	Transport container		
0090	Quality test		

can only be one setup activity per operation the setup key is not specified in the setup activity. Regarding the granulate production process, there is a maximum of five operations. The transport containers cannot be modeled as secondary resources for reasons to be explained later. Therefore they require an operation of its own. The naming of the location is necessary because the location is needed to identify the setup key. Using a graphical representation, the PPM structure is described in Fig. 22.3.

The complete list of operations for this example is shown in Table 22.2.

Every operation possesses at least one *activity*, usually the production activity. In many cases more than one activity will be defined in one operation, to model a single production step. The standard types of activities are "setup", "production", "wait" and "tear down" which all can be used only once in one operation. The activities are marked by an "S", "P", "W" or "T" accordingly. Only the setup activity can have a sequence dependent duration which says the duration is looked up in the setup matrix. If this feature is to be used, the flag for sequence dependent setup must be set. This flag makes it impossible to enter a duration for the setup activity later on in the modes. Another field in every activity determines the percentage of scrap which occurs during this activity. This scrap percentage is used to determine the order size which is necessary to produce the quantity ordered. All of the first three operations in this example have the same activity structure (see Table 22.3).

Table 22.3 Modeling the activities

Activity key	Description	Type	Sequ. dep. setup flag
0010	Cleaning	S	X
0020	Producing	P	

Table 22.4 Transport activities

Activity key	Description	Type	Sequ. dep. setup flag
0070	Container start	P	
0080	Container end	W	

Table 22.5 Quality test activity

Activity key	Description	Type	Sequ. dep. setup flag
0090	Quality test	P	

The transport container and quality test operations do not require a setup activity. So the quality test operation has only one activity type "production", the transport operation has two activity types: "production" and "wait". These activities represent the start and the end of the container usage. APO always lays a so-called cover chain around the activities which belong to the same operation. This guarantees that no activity of other production orders which are also processed on this particular resource is scheduled in between these activities.

The activities for the transport and the quality test operations can be described as shown in Tables 22.4 and 22.5.

Every activity must have at least one *relationship* to another activity. APO does not automatically connect the orders and activities in the way they are numbered or sorted in the tables. This provides a high amount of flexibility in modeling production processes. There are several types of activity relationships already introduced in Chap. 10 which are also used by APO: end-start, start-start, end-end and start-end. For every relation between activities a minimum and maximum time difference can be maintained. The *resource connection flag* at each activity relationship can be used to force APO to use the same primary resource, even if the activities belong to different operations. If the activities belong to the same operation, APO uses the same primary resource anyway, as there is not much sense in doing the setup on one machine and the production on another. The *material flow flag* must be set for every activity relationship which represents an actual flow of material. APO uses this path from input activity to output activity to calculate the total percentage of scrap which occurs during the whole production process.

Generally speaking, all the activities in this example which belong to extruder, mixer or filling machine have simply been connected with end-start relationships and no minimum or maximum time constraints. So they are processed one after the other, and the material can be stored for an infinite time. In fact the system will not let the waiting times between the activities of one operation become too long, as the order would consume transport container capacity while waiting. This would lead to a longer makespan, as other orders have to wait for the containers. This way the optimizer keeps the gaps short and no maximum time constraint is required. Activity relationships are shown in Table 22.6.

Table 22.6 Activity relationship

From	To	Type	Resource flag	Min. deviation	Max. deviation
Produce extr.	Setup mixer	end-start		0	0

The activities of the transport container operation have been connected to the other activities in a slightly different way. The "container start" activity has a start-start relationship to the activity "produce with extruder" with a minimum and maximum deviation of zero. So, the containers are occupied once production begins. The "container end" activity has an "end-end" relationship also with no time deviation allowed with the last production activity (mixer or filling machine). The quality test activity has simply been connected to the last production activity as well.

Every activity must have one or more *modes*. A mode represents an alternative primary resource and may also contain one or more secondary resources which are used simultaneously. Every mode can be given a *priority* from A (first selection) to Z (only manually selectable). This priority influences the resource selection during incremental scheduling and optimization. Actually, the priorities represent penalty costs. If no priorities are used, the system always tries to use the fastest machine first. The mode also contains the information about the activity duration—depending on the resource the mode represents. Selecting the mode with the fastest machine therefore leads to the shortest activity duration. So, in APO the production speed and power of a resource can differ, dependent on the PPM which uses the resource. The resource speed is not maintained with the resource, but with the actual product/resource combination. The activity duration in the mode can be defined with a *fixed* and a *variable* part which grows with the order size. If the activity is a sequence dependent setup activity, the activity duration is taken from the matrix, and the fields in the mode are ignored.

For every mode there are the *capacity requirements* of the resources defined in a separate table. Here also the names of the secondary resources for the specific mode are given. A secondary resource is always covered as long as the primary resource with the same start and end times. The primary resource which is also given in the mode definition is always the so-called *calendar resource*. This says that the times of availability of this resource affect the availability of all the secondary resources in this mode. As mentioned in Sect. 22.3.4 an activity on a single activity resource always has the capacity requirement of 1. On multi-activity resources, capacity requirements other than 1 will occur and have to be defined here. Like the activity duration the resource consumption can be defined using a *fixed* and a *variable* part. In the Tables 22.7 and 22.8 an example is given for the modeling of modes and capacity requirements.

As the last part of the PPM the *components* (inputs and outputs) are maintained. The entries are made for the activity, where the input or output occurs. It is defined whether the material enters or leaves the production process at the begin of the activity, at the end of the activity or continuously. Continuous input and output

Table 22.7 Modes

Activity	Mode	Resource	Dur. fixed	Dur. variable	Break	In shift	Priority
Produce extr.	1	Extruder 1	0	1.5 h			A
Produce extr.	2	Extruder 5	0	2.75 h	X		C

Table 22.8 Capacity requirements

Activity	Mode	Resource	Cap. req. fixed	Cap. req. variable	Calendar
Produce extr.	1	Extruder 1	1	0	X
Produce extr.	1	Worker	0.5	0	

was introduced in the model when in a second step the production of undyed granulate started to be planned with APO as well. Contrary to the production of dyed granulate, which is a batch production process, the production of undyed granulate is a rather continuous production.

22.3.6 Supply Chain Model

Finally all the elements described above must be added to a *model*. A model allows actual planning with the system. Without creating a model the locations, products, resources and production process models cannot be used yet. Using the model philosophy one can create completely separated planning environments in the same system with the data in the same storage device (*live*Cache). Every model can have several *planning versions*. This says that several copies of the transaction data of the model are used to simulate different scenarios and to answer what-if questions. Only one planning version—the active version—is relevant for transferring the planning results back to the connected OLTP system and for receiving new planning data.

22.4 Planning Process

The planning process and the tools involved in this process are presented briefly in this section. The integration with other tools within APO and R/3 is described as well.

The demands used for the production planning and scheduling process are derived from R/3 sales orders (short term) and from APO Demand Planning (long term). At this company there is meanwhile also a tool for the mid term planning (master planning) in use, the APO Supply Network Planning. This tool is on the one hand used to perform a rough cut production capacity check in a horizon of the next 12 months across several business units and all production stages to provide a feedback to the demand planning (the sales people). On the other hand the production amounts created by the Supply Network Planning are passed on to the PP/DS modules (where available) or directly to the R/3 system.

The integration between the mid term planning (SNP) and the short term production planning (PP/DS) is important to perform a consistent hierarchical planning process. As the PP/DS plans only a rather short period of time (in this case 3 months) seasonal changes in the demand structure cannot be taken into account. The PP/DS would not trigger enough production in time respecting the limited resource capacity as the actual future demand is still outside its horizon. The SNP must provide this information to the PP/DS by handing over its own planned production and procurement amounts. In the short term production planning tool changes to this mid term plan by additional sales orders or more detailed resource availability information are made and the production schedule is planned in greater detail as the PP/DS uses more detailed master and transactional data.

In a nightly cycle the PP/DS production planning heuristic performs a planning run which is quite similar to the traditional MRP but which also takes resource and material availability into account simultaneously. The result of this planning run is a production schedule which is already feasible but not yet optimized.

After this production planning run the PP/DS optimizer is used each night to create an optimized production schedule in respect to setup times, machinery costs, delays and total lead time. For the optimization part the standard PP/DS optimizer based on a genetic algorithm is used. This optimized production plan is transferred automatically to the connected R/3 system.

In their daily work the planners use the graphical planning board to check the suggested production plan. Changes which may be necessary are performed using drag and drop functionality in a Gantt chart. Another important tool is the alert monitor which visualizes exceptions in the planning schedule and allows the planners to react directly. All changes which are made to the production schedule are transferred back to the R/3 system online without any delay. The execution of the production plan is still performed in the R/3 system e.g. the release and confirmation of process orders, as these are no planning tasks.

22.5 Results and Lessons Learned

The implementation of APO PP/DS proved to be very successful. As the APO detailed scheduling solution has now been in active use for more than 3 years in the first edition which covers only the dyed granulate production it can be stated that expectations are fully met.

Results show that the quality of the generated plans is as good as that of the plans created by experts. The difference between the plans created manually and those created by APO is the speed and the flexibility in planning: previously, it took several planners more than 1 day to create a production plan which was fixed for several weeks. Now, APO plans the same number of orders in an optimizer run which takes approximately 1 h. The frozen horizon could be reduced from about 1 week to 1 or 2 days. Only one of the planners is involved in the detailed production scheduling using the graphical planning board and the genetic algorithm optimizer, which runs every night. Two other planners can now concentrate on manufacturing execution and other important aspects of their daily work.

A new plan can be created with APO immediately. This is especially important in a critical situation, such as a machine breaking down. The integration with the R/3 system is seamless: no additional steps are necessary to transfer planning results and new orders between the systems.

The quality of the created plans can be measured in terms of production time consumed for a certain number of orders. In this case, the production plan generated by APO usually has a makespan less than the manually created plan. This results mainly from the excessive reserved buffer times which are no longer needed.

A very important factor is the acceptance by the user. This new planning tool has been fully accepted by the production planners who see that they have a powerful system to help them in their daily routine work and make the production more flexible and profitable.

22.5.1 Lessons Learned

Several lessons were learned in this project. One of the most important is that master data quality has to improve significantly in the connected R/3 system. As the R/3 is not only used to perform ERP functionality as before but also has to serve as master data source for an APS the quality of data must be improved. An APS reacts much more sensitive to master data inconsistencies than an ERP system because these master data are used for a very detailed planning process. Master data which are created and maintained for ERP functions will not be good enough.

Furthermore the integration of the planners in the project proved to be crucial. As they have all the knowledge which is necessary to create a good production schedule they must be part of the project from the beginning to ensure success. An APS project can never be brought to life without the planners who are supposed to work with that tool afterwards.

Another big issue is the integration aspect between APS and ERP. Although in this case a very good standard interface has been used, developed by the same software manufacturer of both the APS and the ERP, there was a lot of effort in testing until a smooth integration process could be guaranteed. Without this standard interface much more work, money and time would have been invested in this interface.

22.5.2 Outlook: Further APO Implementations Within this Company

The successful completion of the first APO project has led to further APO implementations at the company. Three more production plants are currently using PP/DS. With the help of experiences gained in the first PP/DS project, these projects were running smoothly and in schedule. In addition to these PP/DS implementations, the Supply Network Planning (SNP) module has been chosen to provide mid-term production planning across all three business units. This supply chain planning process has been in active use since the end of 2002. On the demand planning side, two of the three business units are using the APO Demand Planning module to provide the SNP module with the necessary demand forecast and support the sales people with detailed forecasts. Considering the short term sales and distribution side, the Global Available to Promise module (gATP) will complete the advanced planning functionalities of APO within this company in one of the business units.