SAP Solution in Detail

INTEGRATION OF MANUFACTURING EXECUTION SYSTEMS IN MILL INDUSTRIES

CONTENTS

EXECUTIVE SUMMARY

Many companies, particularly mill industries, operate both SAP® systems and manufacturing execution systems. As can often be the case when combining different systems, past attempts to integrate the two systems have proven to be a challenge. This document provides an overview of existing integration practices and offers recommendations for future directions. It also treats the interfaces and technology that the recommended practices require.

INTRODUCTION: THE CHALLENGES

In mill and several other industries, the scope of many business processes extends to actual production processes. Indeed, many business processes integrate directly with production units. The production-related stages of the processes commonly use special software products known as manufacturing execution systems (MES). Many companies also use SAP software to manage business processes. As a company, we face the challenge of integrating the various components of mySAP™ Business Suite with MES. An additional need is the definition of the relevant software products.

The question of integration is generally solved on a case-by-case basis in individual implementation projects and requires cooperation among the various parties involved: customers, implementation partners, software partners, and SAP. This document helps overcome the challenges of integration by investigating requirements and explaining integration methods.

CUSTOMERS

- Replacement of existing (homegrown) systems
- Need to adapt to a new system and software landscape
- Harmonization of MES systems across multiple mills
- Rethinking of business processes related to production
- Need for better integration of production information

IMPLEMENTATION PARTNER

- Looking for best practices
- Reuse of solutions
- Implementation of scenarios recommended by SAP

SAP

- Numerous and various setups using SAP® software in place
- Recurrent question about best setup
- Customers ask for an answer about possible future setups
- Missing functionality to cover MES requirements

SOFTWARE PARTNER

- Different setup in each project
- Complementary and overlapping functionality vis-á-vis SAP solutions
- Standard products or project-based software
- Customers asking for certified integration scenarios

Figure 1: Integration Challenges

CUSTOMERS

Why do customers develop integration problems at all when they already use SAP software and MES? There are various reasons. Many customers use legacy systems in production-related areas. The legacy systems were often developed for individual customers in customer-driven projects or manufactured by software companies that later vanished from the market or that plan to phase out support services. The consequent unavailability of documentation or of the system's developer leaves customers with a huge maintenance headache, and they find themselves forced to replace legacy systems. At this stage, they often consider a fundamental overhaul of the IT landscape and the redistribution or redefinition of processes to incorporate additional, newly developed functions.

Because acquisitions and divestments of company divisions and individual plants characterize the metal, paper, and textile industries, IT managers face the challenge of integrating disparate IT landscapes and software systems to reduce the high costs of maintaining a heterogeneous system landscape. Besides replacing legacy systems, managers might also consider harmonizing the system landscape at production-related levels. Unlike SAP's business software, however, which provides a holistic business solution for use across divisions, locations, and plants, MES solutions typically focus on individual plants or production areas. Managers must operate and maintain a large number of different systems and integrate the systems with the business world. They not only want standardization of the system landscape, but also the opportunity to transfer as many processes as possible to the SAP system environment to benefit from its strong advantages.

Customers also face increased pressures. The lead-time for supplying mill products has become shorter. Order sizes are also becoming smaller, and customers want to modify their orders frequently – before and sometimes after production. Such commercial pressures increase costs unless moderated by intelligent, integrated, and optimized planning and scheduling.

Customers must also consider the totally different problems posed by the supply chain and by the integration of production-related data in the planning process. Basically, they must discuss how they can best implement planning processes to optimize efficiency. Doing so requires closer integration of various planning tasks (demand planning, rough-cut planning, detailed production planning, logistics planning, and so on) with each other and with the actual situation on the factory floor. Some planning tasks must also be transferred to other areas of responsibility to achieve the best possible results for the company as a whole rather than for a specific production sector.

These reasons also motivate companies to consider restructuring their processes and system landscapes.

The situation is far different in companies whose IT structure exists only at the level of machine control. These companies look to SAP to provide an integrated solution that incorporates production-related processes. In these cases, SAP offers and recommends a complete solution, including a proposal on how to cover the requirements at the third layer (see the section on the layer concept). For certain situations, SAP software alone meets requirements all by itself. But in some cases, SAP might have to suggest third-party software at this level.

IMPLEMENTATION PARTNERS

When implementing production-related processes using SAP software and MES, implementation partners almost always face the twin challenges of integrating the two system landscapes technically and of devising processes that meet the capabilities of the system and the requirements of the customer. The large number of MES and the diverse structures of production plants in mill industries make it virtually impossible to standardize technical integration. However, it is possible to define best practices for the processes and to transfer the practices to other projects. Because each implementation partner has a view of only a part of a customer's situation, partners often ask SAP about the availability of best practices and seek SAP recommendations on the integrated use of SAP and MES software.

SOFTWARE PARTNERS

As noted, the mill sector uses many individual solutions for production-related systems. Companies often develop their own homegrown solutions. In many cases, the software partners in this sector originated in the IT departments of mill manufacturers or in the consulting firms that programmed the MES for the customer. After a while, of course, questions arise about the reusability of certain modules. Can a standard solution be developed in place of the numerous stovepipe systems? One answer is clear: a standard solution of this kind for production plants would have to offer extensive configurability because of the different equipment and combinations of equipment used in processes that might be similar or even identical. Despite the difficulties, customer demands for a standard solution come to SAP.

Depending upon the background of the software provider and its customer's IT history, a situation often arises in which products normally classed as MES cover a range of functions and processes more commonly found in ERP software. If a company decides to introduce ERP software, which system should be used to implement the various processes and functions?

The situation is aggravated if the application of SAP software extends beyond the traditional ERP environment to include supply chain management, and, in particular, production planning. In this case, the overlap not only affects the peripheral MES functions, but also core functions duplicated in the SAP software.

Software companies in the MES field are therefore investigating the most efficient means of distributing functions between SAP software and MES. Of course, this question has commercial implications, which this document does not attempt to analyze.

SAP

The issue of integration poses two significant challenges for SAP. The first challenge arises because customers, implementation partners, and software partners frequently confront SAP with the problems described above. Although SAP is responsible for only a part of the entire solution, it is often perceived as an integrator. SAP must therefore present its partners and customers with solutions that go beyond the exclusive use of SAP software and represent a holistic solution – especially in planning, controlling, and implementing manufacturing processes.

The second challenge concerns process coverage. Here, however, we must make a distinction and differentiate between industries and individual companies in an industry. On the one hand, this situation arises because these industries have very specific processes and requirements that SAP does not even aim to cover. On the other hand, it derives from the scope of coverage provided by current SAP software releases. To meet these requirements, SAP must provide a holistic solution that extends beyond the exclusive use of SAP software.

SUMMARY

This document addresses the situations and challenges faced by customers, software partners, implementation partners, and indeed SAP itself, in the mill products sector. It treats the various issues at stake and suggests solutions. In doing so, it examines the requirements of the system landscape and the process solution in mill industries, especially in the paper, metal, and steel manufacturing industries, and suggests the form that such solutions might take.

Furthermore, this document aims at providing an overview of opportunities for technical integration between the MES and SAP systems.

DEFINITION OF A MANUFACTURING EXECUTION SYSTEM

Although the definition of a manufacturing execution system (MES) differs from country to country, the following describes the main characteristics of such a system for the purposes of this document.

> Manufacturing execution systems deliver information enabling the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing conditions, coupled with a focus on reducing non-value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bidirectional communications.
>
> *Source: MESA International*
>
> *The MESA Web site (www.mesa.org) contains a much more comprehensive definition of MES, which lists 11 separate functions that MESA considers part of MES.*

> A factory floor information and communication system with several functional capabilities. It includes functions such as resource allocation and status, operation/detailed scheduling, dispatching production units, document control, data collection and acquisition, labor management, quality management, process management, maintenance management, product tracking and genealogy, and performance analysis. It can provide feedback from the factory floor on a real-time basis. It interfaces with and complements accounting-oriented, resource planning systems.
>
> *Source: APICS Dictionary, 9th ed., APICS 1998.*

THE LAYER CONCEPT

In many production-oriented companies, tasks and responsibilities in the IT landscape are assigned to different layers. The common approach is a layer concept with four to five layers. Each layer is assigned different tasks and different areas of responsibility. Accordingly, the number of IT systems and the hardware and software technology used on each layer can vary significantly.

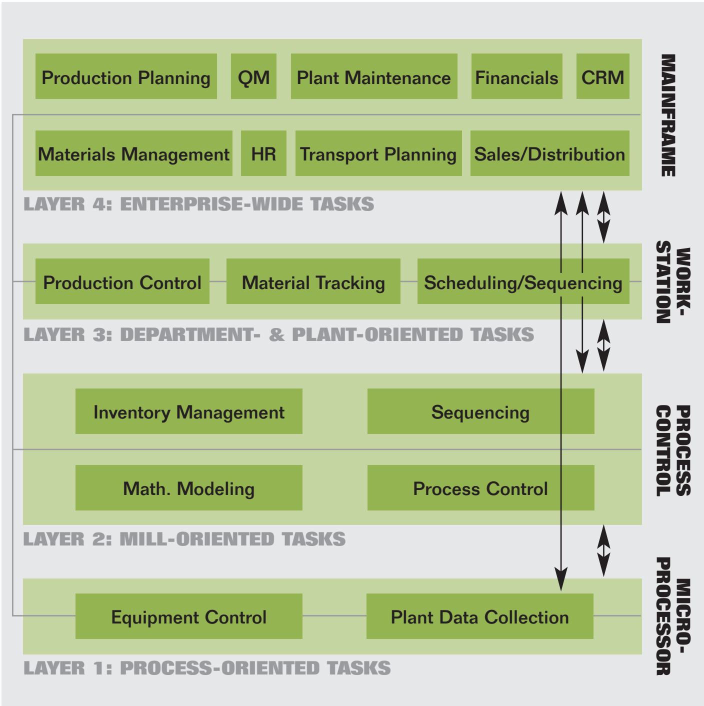

Figure 2: The Layer Concept

Systems for direct machine control and plant data collection are found at the lowest layer. Layer 1 typically maps requisite microprocessor systems or programmable logic controllers (PLCs) directly to the machines and production units.

A system's area of responsibility is restricted to a particular machine or production unit, which can lead to a correspondingly high number of systems at this level.

The second layer contains the process control systems (PCS). These systems control a production area, such as the hot rolling mill in the steel industry. The systems and production units at this level also manage processes using optimized mathematical models and trace the materials that pass through the plants. For example, a system at this level might be responsible for controlling a steel converter, depending upon the grade of steel to be manufactured and the raw materials being used.

The third layer is responsible for the production control of a larger area, such as a plant. For example, the processing sequence of pieces is planned at this layer, as is material tracking. The particularities of mill industries assign extra significance to tracking material stock levels from plant to plant. In mill products industries, tracking stock levels involves more than simply recording quantities. Individual materials must be tracked throughout the manufacturing process. The IT systems are referred to as MES at this layer.

The fourth layer handles production planning, quality management, shipment and dispatch, maintenance management, and, generally on the higher sublayers, supply chain management. The fourth level traditionally houses ERP systems, such as SAP R/3® or supply chain management systems, such as SAP Advanced Planning & Optimization (SAP APO).

OVERLAPPING FUNCTIONS

As noted, one of the focal points of this document is the distribution of processes and functions between SAP systems and subordinate systems. The production planning, production execution, and logistics processes can be subdivided into several groups, depending upon which system provides the required functions.

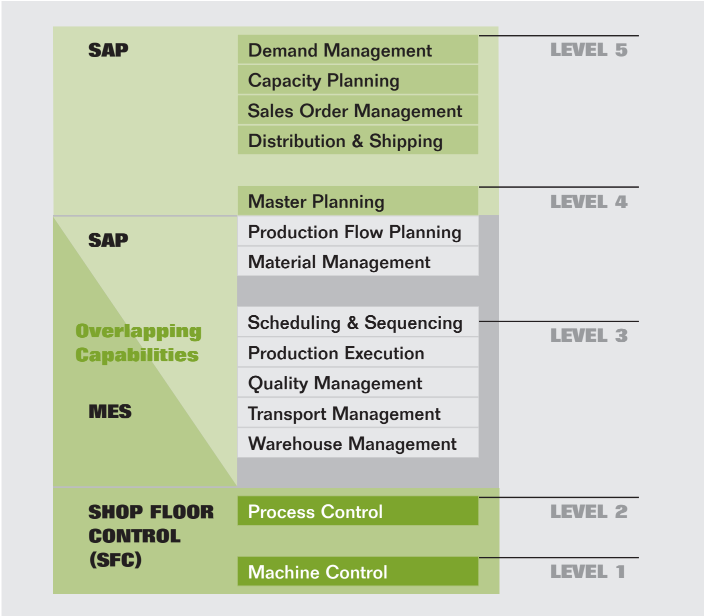

Figure 3: Overlap Between SAP® Functions and the Functions in Subordinate Systems

The first group contains processes, such as demand management, sales order management, and distribution that can be assigned only to the SAP level.

Machine control and process control are definitely assigned to the subordinate systems on levels 1 and 2. These levels are even lower than the MES. At least in the case of level 1, they often form part of the machines and plant installations themselves. Several processes between levels 3 and 4 cannot be clearly assigned to SAP systems or to the MES. Two options come to mind for processes at this level: they are modeled either in SAP software or in the MES. A decision on which option to adopt depends upon the actual requirements in each case and upon the corresponding capabilities of the MES and SAP systems.

More often than not, however, the overall process spans both system environments because of the (intended) restrictions in the process-coverage level provided by the SAP and MES modules: neither system covers all aspects of the process fully. Integration is required with the environment of levels 1 and 2 and with the processes and data flows in the SAP system.

Figure 4: Grey Zone Between SAP® Functions and the Functions in Subordinate Systems

Cooperation between the two systems is often necessary to model the complete process. Consider the following examples.

The steel industry increasingly uses online systems for optical surface determination to assure the quality of coils. These systems generate enormous quantities of data in real time. The data must be processed at a production-related level to allow determination of a process-control strategy. A coil might then be removed from the subsequent production process for reworking. Only an MES can manage this part of the quality assurance process. However, aggregate data is then generated from the virtually raw data. For instance, a quality characteristic is generated for the batch to which the coil is assigned in the SAP system. The quality characteristic is required in the quality management (QM) component and for controlling subsequent business processes. The complete process begins at level 1 or 2, passes to the MES, and then continues in QM. Each part of the process must be managed in the relevant system.

Transport management serves as a second example. The transport management functions in SAP systems focus on transportation between plants or between production plants and distribution centers and customers. These functions do not cover transportation within an individual plant. Yet, especially in the steel industry, considerable distances often must be covered between different facilities in the production process (blast furnace, steel plant, and hot rolling mill); the management of transport logistics is a key task. In this example, the MES would be responsible for transportation within a plant, but the relevant SAP functions would cover planning, optimization, and the management of transportation to the customer.

Warehouse management provides the final example. In SAP systems, a material can be processed in the materials management (MM) or warehouse management (WHM) components only if it is a stockable item, that is, if it has a material number. Yet in mill industries, depending upon the given process, a significant amount of work-in-process is often found between production steps. This material will not be mapped in an SAP system if it is within one material level. The system not only must monitor the storage bin (which is available only with restrictions), but also must allow the entry and selection of individual pieces. The control of cranes to transport the pieces for further processing is a related consideration. Because the material cannot be mapped by piece in the SAP system, the process must be managed in an MES.

Even if the SAP system tracks the material, in some cases the information in MM or WHM is insufficient for detailed process control. For example, in a slab yard, the exact position of the slab in a stack is not the only important information. Its temperature and the temperature of the environment can also be considered to improve the subsequent production process.

APPLICATION AREAS FOR MES IN MILL INDUSTRIES

The challenges described above are often not even a factor in other industries. There, the SAP production planning (PP) component or the SAP production planning for process industry (PP-PI) component communicates directly with the systems at level 2. Why is this so seldom the case in mill industries?

There are many reasons, three of which we will examine in more detail.

Volatility of Production

In mill industries, and in particular the metal production industry, the production process cannot be fully controlled and the plans cannot always determine the outcome of processes. In addition, the large number of characteristics for the manufactured products and customer behavior necessitate changes on short notice. It soon becomes clear why companies in this sector are commonly forced to perform reactive planning (described below). Essentially, reactive planning means that the result of the previous step must be evaluated to determine the next production step. Quite often, some of the units processed do not have the required specifications. A decision must then be made on how to process these units further.

Complex Machine Scheduling

Because of the involvement of many machines and production units, technical constraints and other production conditions require planning the sequence in which to process materials. Such planning cannot be performed until the material characteristics are known, so it might have to occur on short notice. One example is the coffin-shaped sequencing in metals processing, where the hot- and cold-mill schedules interact complexly with the annealing furnaces. Another example, from the paper industry, is the situation with off-line coaters and paper machines, where the basic rules of paper-machine scheduling must be balanced by quite different rules for the coater, although the scope of holding work-in-progress between the two can be limited.

Quantity- versus Units-Based Handling

Companies in mill industries typically describe the products to be produced or processed in three-dimensional terms. Both quantities and single piece must be recorded. The properties of single pieces usually must be described by several hundred characteristics. Consider the example of a customer who orders 200 tons of a specific type of steel in the form of coils. The sales order leads to the casting, rolling, and further processing of several slabs. Each individual slab belonging to the order, and each coil, must be mapped from the moment it is first produced. Single coils might pass through very different production paths, especially if any reworking is necessary. Single pieces might also need to be removed from the package for the original sales order because they deviate too far from the required specification.

These issues are uncommon in processes mapped in an SAP system, which means that specialized systems must be used. Again, however, we face the question of how best to distribute the tasks across the systems, considering the origin of the systems on levels 3 and 4 and the extended capability of the SAP systems.

INTEGRATION ISSUES

A number of issues must be considered when different systems and processes are integrated in production planning and control. They can be grouped under the headings of planning horizon, visibility, ownership of plan, and reactive planning.

A plan describes the information required to execute production. However, different systems might assign specific parts of a plan a different status. In an SAP system, planned orders represent the parts of a plan still in the planning phase, released production orders represent the parts released for execution, and production orders map the parts already at the execution stage, some of which might have been partially confirmed.

Planning Horizons

Duration, or lead-time, is one characteristic of the production process in mill industries. Some processes are almost continuous, some wait-times for processes increase the total lead-time by several days, and some technical conditions in some other processes combine pieces from different orders and process them together. This situation leads to rolling horizons across the various production-unit levels, which makes it difficult to monitor and control the plan, particularly in the metal and steel industries, because planning horizons and execution horizons overlap across the different production levels.

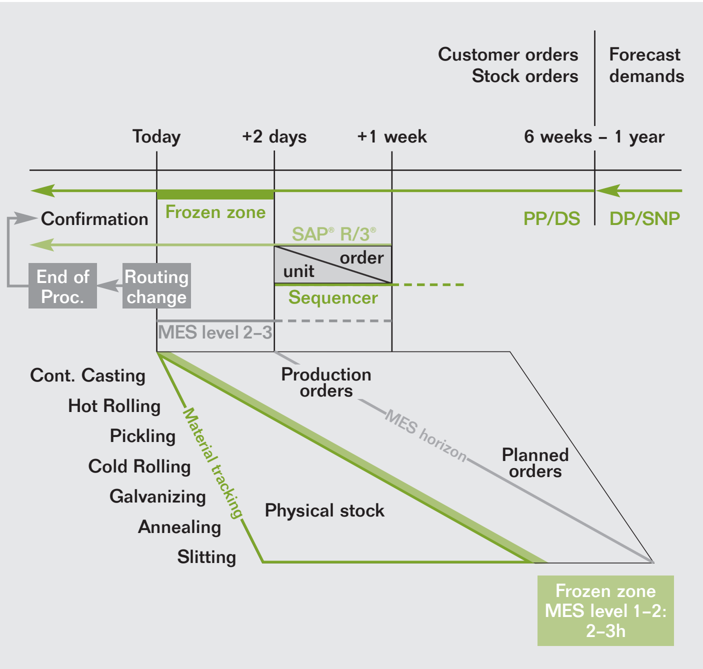

Figure 5: Planning Horizons

The figure above illustrates this situation. When the plan for the continuous casting plant is already in the execution stage, planning for the finishing line is still in the planning horizon. Deviations between the actual situation and the planning situation will necessarily affect planning of the subsequent levels, especially regarding deadlines and the specification of the materials. Obviously, plans for each stage of the process should be released only when the status of the starting material is known. However, doing so requires close integration between the MES, which provides information on the status and result of production, and the planning system. Above all, the planning system requires comprehensive feedback in real time.

This need is undoubtedly one of the major reasons that planning takes place completely at layer 3 in current implementations of production planning and production control. We will examine the advantages of alternate approaches later.

Visibility

Whichever systems are used in the complete production planning and control process, two important questions arise. Which system sees which part of the overall plan at a given time? Which system(s) can make which changes to the plan?

Ownership of Plan

Problems will always develop when two different systems make changes to the same part of a plan. Doing so requires close synchronization between the systems. The following describes the existing approaches. The particular structure of each approach can often be traced back to the problem described here. As a cost of avoiding synchronization, these approaches tend to forgo functions in the relevant systems.

Reactive Planning

Reactive planning refers to the creation of a practicable production plan that has been optimized to meet the conditions known at the time. Of course, during execution of the production plan, the information used to create the plan might change. Indeed, this is a common occurrence in mill industries. For example, customers might subsequently change their orders or the result might differ from the plan, perhaps in terms of the produced quantity or of the characteristics of the produced material. The system must react to deviations of this kind, and the reaction must occur at different levels. The deviations can often be corrected by simple intervention on-site by a responsible employee. One of the relevant planning systems does not have to manage these kinds of corrections. It is enough to import the result at the end of the correction, for example, to post the actual quantity, actual processing duration, or actual material characteristics.

The situation is different when one of the planning systems must make the correction. This need might arise because the correction affects more production units than first thought or because the subplans for other production levels are affected and must be corrected. The choice of which system in which to restart the planning process now depends upon the distribution of tasks between the planning systems and upon their planning horizon – in terms of both time and content.

Consider the example of a process that involves several planning systems. In this case, the subordinate planning system should not intervene at the higher planning level of the superordinate system, which would entail synchronization of the result with the superordinate planning system. This approach might seem simpler to those faced with an exceptional case. However, it would prove fatal to any attempt at complete optimization of the production and processes. If we assume that the subordinate planning system maps only a section of the overall plan, and only that part has been released for production, the status of the overall plan might well have changed somewhat in the meantime. Synchronization from the viewpoint of the subordinate system would cause severe problems.

SCOPE OF THIS DOCUMENT

As indicated above, many processes are integrated across the MES and SAP systems. This document deals only with production planning processes, that is, the planning, optimization, control, and execution of the actual production process.

This document does not consider the processes involved in logistics (purchase order and shipping processes), company transportation, or warehouse management. Each of these areas requires a separate discussion.

EXISTING INTEGRATION SETUPS

Some companies already integrate MES and SAP systems directly. However, the degree of integration differs markedly and there is no typical setup. The solutions are more or less tailor-made for each company, depending, for example, upon the hardware and databases available. Furthermore, the solutions have been developed in stages over a long period and the technology used reflects this type of development. In the following, we will examine a few typical situations. Note that many variations also exist.

SAP R/3 (WITHOUT PP) AND MES

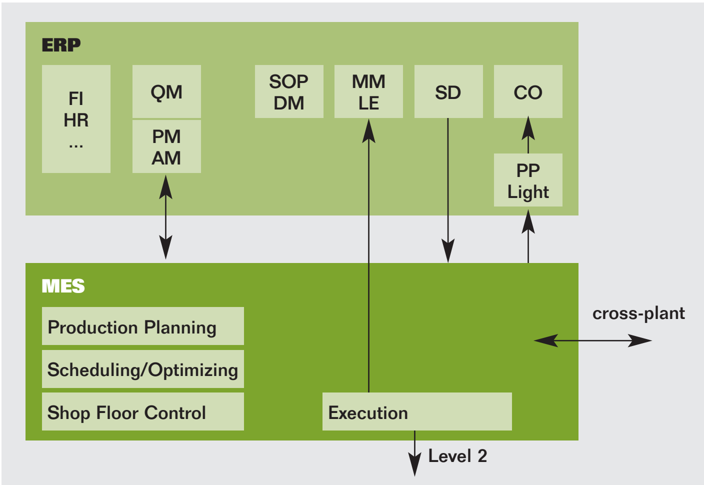

Figure 6: SAP® R/3® (without PP) and MES

A very common setup consists of SAP R/3 and an MES with numerous planning functions.

Based upon make-to-order production at the highest product level, this setup uses the SAP sales & distribution (SD) component to enter sales orders. The MES handles production planning, material procurement, logistics, and quality management; cost determination and billing is executed in SAP R/3.

The sales order is created in SAP R/3 and its requirements transferred to the MES. From this point onward, the MES is used for all other planning processes. Accordingly, a production plan that takes account of the requirements is created in the MES. Using this plan, which might be created once a day, a confirmed delivery date for the sales order is then transferred to SAP R/3. Confirmation of the delivery date can be transferred to SAP R/3 only after the plan has been created, although it can be confirmed immediately if the MES has the required functions. The only information transferred to SAP R/3 at this point is delivery related. The production orders planned in the MES, which are therefore recognized only in the MES, are then released for production and execution. Confirmations of activities, quantities, and quality data are entered in the MES.

Only selected parts of the data are transferred to SAP R/3. For example, when a single operation has been completed in the MES production order, the MES triggers the creation and release of a production order in SAP R/3. The production order contains only that particular operation. The SAP R/3 production order and the data previously entered in the MES are then assigned the status of completed. The PP component is therefore used indirectly and only as a basis for creating the controlling-relevant production order. The MES carries out the actual production plan. The costs can be calculated from the production order in SAP R/3 and its confirmation.

The costs of the sales orders are then calculated by assigning the various production orders to the sales order. Depending upon the particular setup, QM data is then also entered in the MES and, after having been reduced to a few relevant values, transferred to SAP R/3.

Advantages of the method:
- SAP R/3 can enhance the existing MES cost-effectively.
- Because a major part of the MES is programmed specifically in most cases, the functionality meets the particular requirements of each customer.

Disadvantages of the method:
- No production planning view in SAP R/3, so that two systems are used when information about the current status is required.
- Data distributed across two systems causes high data-maintenance costs and data inconsistencies.
- Because the MES in this case is more than just an execution system, it normally has its own data model for master and transactional data. Communication between the SAP system and the MES is therefore not only a technical issue but also a data-mapping issue. Master data and transactional data objects must be mapped in two directions between the SAP system and the MES. In most cases, bidirectional mapping is impossible without the loss of information and consistency.
- Plans can be created only for individual production areas. No optimization of the production plan across several production areas is possible.
- Many interfaces are required, which causes high maintenance costs and effort.
- Customization and the high number of interfaces lead to a high total cost of ownership.

Due to the above-described disadvantages, we do not recommend this integration method. In the chapter “Recommended Approaches”, we reassume them and provide answers to solve these issues.

SAP R/3 (WITH PP) AND MES

This model combines SAP R/3 and an MES with few or no planning functions. Unlike the previous one, this model fully uses the PP, MM, and QM components in SAP R/3.

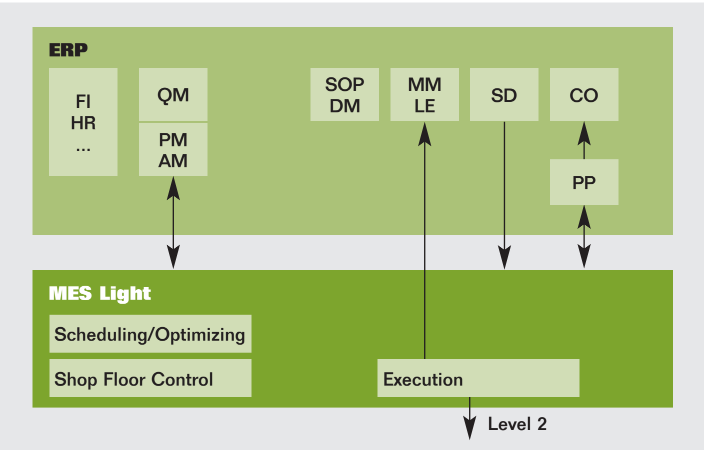

Figure 7: SAP® R/3® (with PP) and MES

In this example, the sales order is created in the SD component; SAP R/3 performs an available-to-promise check to confirm the deadlines. Subsequent stages of production planning are then managed in PP. If the planned order is converted to a production order in SAP R/3, the data for the production order is transferred to the MES shortly before the start of production. The production process is managed in the MES. If necessary, minor changes to the production sequence may first be carried out manually. These changes cannot be mapped in PP because they deal with variances in the actual production process; they are not transferred to SAP R/3. Confirmation of order data (activities, quantity, and quality data) is sent directly from the MES to SAP R/3. This situation is found only in relatively simple production processes because it is difficult to implement changes to production orders during production.

Advantage of the method:

- All the data managed is in one system without data inconsistencies.

Disadvantages of the method:

- Planning can occur only at the plant level; no cross-plant optimization can occur.
- Limited planning functions
- Complex production processes are difficult to map.
- Very often the update from MES to SAP R/3 occurs late (at the end of the complete production process). Therefore, the visibility of the production status in SAP R/3 during the production process is still very limited.

Due to the above-described disadvantages, we do not recommend this integration method. In the chapter “Recommended Approaches”, we reassume them and provide answers to solve these issues.

SAP R/3, SAP APO, AND MES

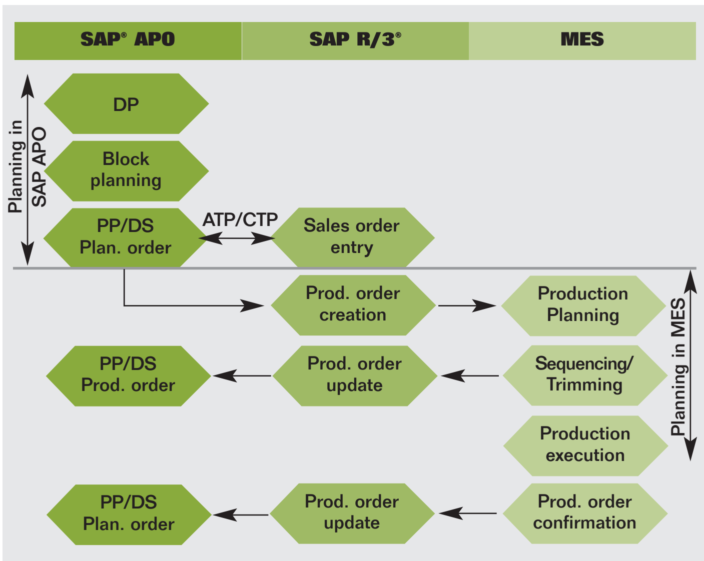

Figure 8: SAP® R/3®, SAP APO, and MES

This method involves SAP R/3, SAP APO, and the MES. It distributes the planning functions between SAP APO and the MES; SAP APO Demand Planning (DP) is used for mid- and long-term planning. Production planning blocks are created in the SAP production planning/detailed scheduling (PP/DS) component. The blocks define the periods in which a particular machine will produce a particular product.

If a sales order is created in SAP R/3, a check is run in SAP APO to see if the required stock is available or if a production order already exists to cover the requirement. If not, a planned order is created in SAP APO to cover the requirement, and the confirmation date is the next date on which a block has free capacity to produce the relevant product. Scheduling takes place at the end of the block, that is to say, at the latest time. Accordingly, a planned order can be moved to a later date within the block without affecting the confirmed delivery date.

The planned orders generated in this manner are then converted into production orders at the latest possible point. The core interface (CIF) transfers the relevant production order to SAP R/3; from there it is imported to the subordinate MES. The MES runs a detailed optimization of production, taking machine, cycle, and sequencing factors as well as information about partially executed production orders into account. The MES might also use industry-specific optimization tools at this stage, for example, to optimize the rolling sequence in the steel industry or run trim optimization in the paper industry.

At the start of production, the production order is released to production by the MES. The data generated during production is compiled and transferred by the MES using interfaces to SAP R/3, which is also the starting point for updates to SAP APO. If the production order is complete, it receives final confirmation and the produced quantity is posted to stock in SAP R/3.

Subsequent process steps, such as delivery and invoicing, are executed in SAP R/3. The costs are also calculated by SAP R/3 using the data it has received.

Advantages of the method:
- Advanced planning functionalities are possible using standard integration between SAP APO and SAP R/3.
- Planning optimization takes the overall situation into consideration, not just the shop and production stage.
- Clear dedication of planning tasks to SAP APO and MES (ownership of data).

Disadvantages of the method:
- Planning functionality is still distributed into two systems, depending upon the stage and time.
- Planning might produce conflicting results because it occurs twice.
- Synchronization effort
- Data-object mapping between the involved planning systems is still difficult.
- Planning logic must be built and maintained twice.

Due to the above-described disadvantages, we do not recommend this integration method. In the chapter “Recommended Approaches,” we reassume them and provide answers to solve these issues.

TECHNICAL INTERFACES

In the integration methods described above, master and transaction data, such as sales orders, planned orders, production orders, goods movements, routings, bills of material, scheduling data, confirmations, and so on are exchanged between SAP software and the MES using core interfaces in SAP R/3. Plant data collection (PDC), the production optimization interface (POI), and the industry-specific optimization interface in mySAP Supply Chain Management (mySAP SCM) are used along with many of the 1,500 BAPI®s offered by SAP. For more information about SAP standard interfaces and integration technology, see the section on interfaces and technology.

But the interfaces have specific behaviors that have to be considered, for instance, when updating production order data in SAP R/3 that has already been transferred to the MES. A delta download of the data changed in SAP R/3 to the MES is not intended to avoid jeopardizing the production plan within the MES system. To guarantee the data supply, the order must be deleted completely and created anew to include the current data. In the opposite direction, SAP R/3 allows order data to be changed in the MES and updated in SAP R/3 before the bills of material (BOMs) are exploded. The limitation, that no characteristics could be transferred to the MES, to be considered during production planning, could be solved using the new IDoc LOIPRO, which will be available with the next SAP for Mill Products release.

In SAP R/3, incoming data is always processed immediately. SAP interfaces operate so that real-time processing of data occurs as soon as the data is received. Buffering the data before being process is not intended due to the real-time architecture of SAP software. However, such a buffer can be realized and respective functionality is available.

IMPLICATIONS OF THE CURRENT INTEGRATION MODELS

The models described above show the challenges involved in integrating systems, modules, and processes between the SAP landscape and the landscape of subordinate systems, such as MES, in particular.

We will now examine various solutions to these problems. First, we will make some basic observations that we will then use to suggest alternate integration approaches.

REASONS

A fundamental challenge that crops up in the current approaches is the separation and distribution of planning tasks among several systems. In earlier methods, this problem was restricted by foregoing functions in the PP component, for example, and by transferring many tasks to the MES. In this case, almost all aspects of production planning are managed in the MES. Doing so ostensibly solves the problem of planning levels and synchronization. However, it hinders optimization of the company's supply chain. As described in the introduction, MES are typically responsible for individual company areas. Any information that flows between the MES is limited to materials transported from one production area to another. Visibility or even optimization of the overall process flow across all company areas is practically impossible. In the past, this limitation did not pose a great problem, partly because companies were run according to a strategy of local optimization and partly because no systems were available for optimizing the supply chain (supply chain management systems and advanced planning systems). However, the changed market situation and the availability of systems for planning and optimizing on a company level, or even on a cross-company level, influenced company strategy and the shortcomings of the existing solutions soon became evident.

Today's planning systems are increasingly used to optimize the supply chain. Advanced planning systems like SAP APO, a component of mySAP SCM, map material, value, and information flows in a company and enable integrated planning and optimization of the flows. The company's sales targets are defined in a centralized, mid- to long-term, demand and production planning process based upon historical data and forecasts about future developments. This approach leads to the creation of a rough-cut production plan that optimizes available production capacities.

This information creates the foundation for the detailed production plan, which maps out the supply of raw materials and the manufacture of intermediate and sales products to meet the forecast requirements of actual sales orders. At the same time, this plan takes into account the available vendor and production capacities and the supply of required starting materials.

With this form of integrated planning, the company approaches overall optimization of its production processes and improves its customer service by offering more reliable commitments. In the intermediate approach described above (SAP R/3, SAP APO, and MES), a planning system of this kind is then integrated into the existing system landscape. The immediate result is a situation in which two planning systems, SAP APO and the MES, can access and change the same subplan. SAP R/3, which functions as a business process execution system, separates the two systems. The process switches alternately between planning and execution systems, using SAP APO as the planning system, SAP R/3 as the business process execution system, the planning functions in the MES as a production-related planning system, and the execution functions in the MES.

Furthermore, the boundaries between the areas of responsibility of the two planning systems are unclear. Because SAP does not offer an industry-specific optimization algorithm within SAP APO, these functions must be implemented in the MES. Before the MES can implement the optimization functions, however, it requires access to a large part of the overall plan. The result of planning and optimization affects the overall plan, so that synchronization between the two planning levels must occur. Without synchronization, the plan in SAP APO would not be up to date, which would largely defeat the purpose of using an advanced planning system.

Synchronization between SAP APO and the planning functions in the MES presents various challenges, however. The question remains whether it is possible to synchronize two instances of a plan that are changed independently of one another, and other fundamental aspects of data processing also hinder a satisfactory solution.

Before the planning functions in the MES can begin their tasks, the plan must be released – at least in part from SAP APO to SAP R/3 and from SAP R/3 to the MES. However, this process requires that production plans with planning status (planned orders in SAP systems) be released for execution. In SAP R/3, planned orders are usually converted to production or process orders before being released and transferred to the MES. Therefore, the status of the plan is changed before the planning process has concluded. This process also necessitates conversion of a planning object (planned order) into an execution object (production order). By its very definition, an execution object can be changed only under certain restrictions. However, the changes conflict with the plan that is now underway in the MES.

This brief example highlights the numerous data-processing, process-logic, and paradigmatic problems created by an approach such as the one described above. These problems cannot be solved without a fundamental rethinking of the business processes related to production.

AN APPROACH TO A SOLUTION

The approach to a solution that uses the intended approaches described below is based upon a fundamental decision to combine planning levels.

This decision necessitates several IT-based changes and a remodeling of the complete system and process.

Since it is not SAP's strategy to provide solutions for all characteristics of planning challenges as components of standard systems, the first requirement is to integrate SAP APO with the relevant tools or industry-specific planning and optimization algorithms. From a technical perspective, integration is achieved using standard interfaces and substitution processes. This form of integration fundamentally differs from the integration between SAP APO, SAP R/3, and the MES. Here, the third system is used as an extended workbench for SAP APO planning functions and processes. SAP APO already contains solutions for the technical problems of integrating such a third system because of its modular design.

By combining the required planning tools in this manner, it is therefore possible to create a practicable, optimized plan at a single planning level. Only when the plan has been created in full and when part of it is passing through the execution horizon, is it transferred to the implementation systems, namely to SAP R/3, the business process execution system, and then to the MES, the production-related execution system.

It is no longer necessary to synchronize the two planning systems during the planning process.

The actual feasibility of this logic and its ramifications depends to a great extent upon the type of model used.

To illustrate this situation, let's relook at the production process in steel manufacturing. This process involves many levels and lengthy lead times. Each stage of the production process can be defined only when the result of the previous process is known.

A model that groups all production steps into a single production order would require the transfer of the complete order from the planning system to the execution systems at the start of the first production step (operation). A refinement of the subsequent production steps, using either actual-data feedback from production or other changed parameters, would have to be treated as reactive planning in the MES. This approach would run contrary to the concept of planning at a single level, dealing as it does with only one part of the plan. Alternatively, the plan could be refined at the planning level using the execution objects, that is to say, the production and process orders. However, this too would implicate other restrictions.

In the model, therefore, the plan should be separated at predetermined breaking points. All the production steps between the breaking points are released together and transferred to the execution levels. Decisions that must be made during this production step can be made locally in the MES. These decisions have no direct, long-term effects. It is sufficient if the planning level receives feedback about changes so that it can adjust the next subplan before it is released, if necessary. The execution level needs to know only about the available order stock to react appropriately.

Of course, there are exceptions to this rule that do require direct feedback from the execution level to the planning level. Nevertheless, empirical evidence suggests that these exceptional cases can be confined.

The subplan released to the execution level is fixed for the planning system. It is regarded as a constant until the orders have been completed or until feedback from the implementation level necessitates a general replanning for this area too.

RECOMMENDED APPROACHES

PLANNING PROCESS WITH TRIM OPTIMIZATION

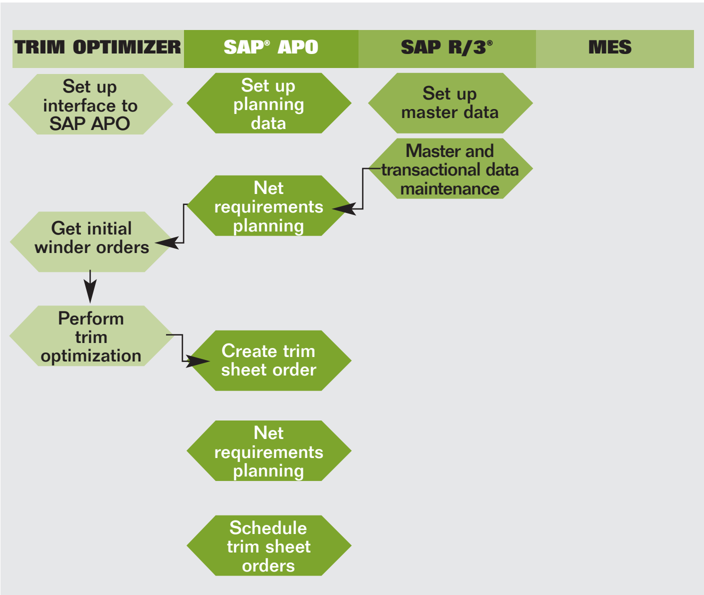

Figure 9: Planning Process with Integrated Trim Optimization (Part 1)

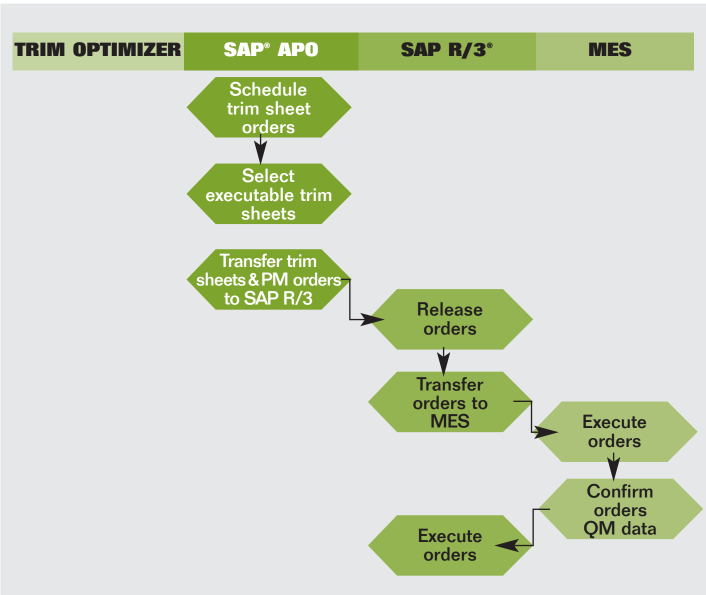

Figure 10: Planning Process with Integrated Trim Optimization (Part 2)

Many paper mills involved in the manufacture of roll products, packaging paper, and so on use a relatively simple process. The raw material in the paper is processed into pulp. The paper machine produces jumbo reels, which are then transported directly to a winder, where they are slit into smaller reels. These reels are usually packaged to produce the end product.

The problem of trim optimization crops up even in a situation as apparently simple as this because customers order the end-product reels in a variety of dimensions.

The following approach uses SAP APO on a very limited basis. Nevertheless, it has specific advantages for customers:

- Use of the standard interface to integrate the trim optimizer into SAP APO. Integration into SAP R/3 would require customer-specific interfaces.
- Standardized mapping of the trim sheet. The trim sheet can be transferred from SAP APO to SAP R/3. Generating the trim sheet directly in SAP R/3 or using an interface to a trim optimizer would again require customer-specific programming.
- Once the trim sheet order is in SAP R/3, production can be reported against it, material consumption and other costing information can be recorded, and quality attributes can be archived.
- Use of PP/DS tools in SAP APO. For example, the user can employ the graphical planning board to execute interactive sequencing of the generated trim sheets without having to use the advanced planning algorithms in SAP APO. The trim order also allows detailed timing of the production orders through pegging, which has direct relevance for transportation planning.
- Increased flexibility of generating several versions at once and valuating them within the overall context of production, procurement, and delivery

The use of SAP APO in this simple approach also gives customers the option of later adding other processes or variants, such as the availability check (ATP or CTP), finite scheduling in PP/DS, demand planning, and supply network planning.

To use the trim optimization interface, the product must be modeled as a configurable material or product variant. This applies not only because a great deal of information needs to be transferred via characteristics to the trim optimization system, but also because the products (reels) that result from trim optimization can be mapped appropriately only by using configurable products or their variants. In SAP APO, characteristics-dependent planning (CDP) must be used.

To execute trim optimization, the initial orders are transferred to the external system. Depending upon the capability of the external system, additional data must also be transferred simultaneously. If the trim optimization system has its own means of data maintenance, the master data might have been transferred in advance. In general, however, it is preferable to maintain single sourcing of such data to avoid the synchronization issues that would otherwise arise. One may therefore talk of a stateless trim optimization system.

After trim optimization, the result is returned to SAP APO as a trim sheet order. The existing initial winder orders (and paper machine orders) are deleted or adjusted (assuming that only a part of the order quantity was used to create the trim sheet) in a subsequent planning run in SAP APO. The planning run can also be started directly in the trim optimization system, as can the scheduling of the trim sheet order and any other related orders.

Transfer of planned orders to SAP R/3 takes place shortly before production.

The production orders in SAP R/3, generated by the transfer of the trim sheet order from SAP APO, are usually returned to the subordinate execution systems upon or after being released. What's the advantage of mapping the trim optimization result as a trim sheet order? No conversion has to be made in this interface because the MES can also be used to implement trim sheet orders.

Subsequent stages of the process monitor and confirm the production of jumbos. The resulting characteristics, such as actual dimensions and quality characteristics, are transferred back to the relevant processes and objects in SAP R/3. When a jumbo's actual and target characteristics diverge significantly, it might be necessary to adjust the trim sheet to take account of this new data (which can take the form of unplanned goods receipts). Since only existing data is used, however, doing so has no direct effect on the planning process. Instead, a re-trim is carried out locally. The re-trim is essentially no more than a restricted trim optimization tool. Indeed, the result may also be maintained locally. The SAP systems receive feedback only in the form of confirmations and goods movements. The planning level is not involved in the process until access to orders outside the MES horizon is required to attain useful results.

The advantages of this method are undoubtedly the increased planning reliability and the vastly reduced functional requirements for the MES. Various aspects of the production plan can be optimized at a relatively early stage, which not only improves trim optimization for a winder, but also achieves overall optimization across all production steps. The result of the trim optimization affects the overall plan, but can be used directly in planning in this method. It is therefore unnecessary to synchronize different planning levels and systems.

PLANNING PROCESS WITH SEQUENTIAL PLANNING

The following section describes an approach that takes industry-specific optimization tools and the MES into account. The model is based upon quantity-based planning in SAP APO and piece-based planning in the MES.

In this case, rough-cut planning is performed in SAP APO: the quantities to be produced are planned roughly using the DP component, and blocks are then derived and used for production planning in PP/DS. The procedure described here uses block planning in SAP APO and is one method of mapping the planning results determined in SAP APO DP to SAP APO PP/DS. It is one possible option – but not the only one – and has been chosen as an example because it is used often.

If a sales order is entered in SAP R/3, SAP APO performs an availability check to see if the relevant stock is available or if a planned receipt (production order, planned order, or purchase order) already exists to cover the requirement. If not, a planned order is created in SAP APO to cover the requirement. The confirmation date depends upon the next free capacity of a block for the relevant product. The order is scheduled for the end of the block, the latest possible time within a block. That means that the planned order can still be moved later on to an earlier time within the block for production reasons, without affecting the delivery date as confirmed in the sales order.

An industry-specific optimization tool optimizes the planned orders in SAP APO according to the logic implemented. The result is imported back into SAP APO. This approach allows the movement of orders between individual blocks, for example, to improve planning from an optimization perspective.

Rather shortly before the start of production, planned orders are converted to production orders and transferred via SAP R/3 to the MES. When the data for the quantity-based SAP R/3 production order is transferred to the MES, the corresponding piece data is generated and used for further planning in the MES.

Detailed planning is started in the MES, and the industry-specific optimization tool is used again, but this time on a piece basis, so that even pieces from different production orders can be combined into a production lot for product optimization. This planning also takes into account production orders that have been started, and quantities, even single pieces, produced at intermediate stages.

The plan is not transferred to SAP R/3; it is kept only in the MES. Exceptions, such as delays, are determined in the MES and noticed only at this level. Otherwise, the situation in SAP R/3 and SAP APO remains as it is, and an update occurs only upon the basis of the confirmations from production, which are entered in the MES and then transferred to SAP R/3. An inconsistency then exists between the planning situation in SAP APO and the MES, but it is not critical because the MES is responsible for all production orders in production, and SAP APO for all planned orders not in production. It is impossible to optimize the plan overall, since neither system reacts to changes in the other system or consolidates the changes for optimization. This situation is also due to the quantity and piece issue.

If production is complete, the final confirmation is posted by the MES to SAP R/3 and stock receipt postings of the produced quantities are made. The process takes place in SAP R/3 from this point: delivery creation, cost accounting, and so on.

Advantages of the method:

- Planning is integrated.
- Cross-plant planning is possible.
- Planning quality is improved, because a better selection of production orders gets to the MES.

Disadvantages of the method:

- Planning logic is still distributed between two systems.
- Double logic is required for the industry-specific optimization tool (quantity and piece).
- Interfaces are required from the optimization tool to SAP APO and the MES.

PLANNING PROCESS WITH CENTRAL PLANNING

This approach merges planning in one place, based upon the use of SAP APO, SAP R/3, MES, and industry-specific optimization. The prerequisite? The entire model is piece-based. The model requires one production order per piece and operation. Only in this way can production planning react flexibly to production variances, and individual pieces be put together in individual operations.

Mid- and long-term planning takes place in SAP APO DP. Based upon past data and planned future sales, requirements are generated in advance and can later result in purchase orders for starting materials and so on.

The following description is based upon the use of block planning in SAP APO. The block planning function is one method of mapping the planning results from DP in PP/DS. It is one possible option – but not the only one – and has been chosen as an example because this option is used often.

Based upon the planning data, blocks are set in PP/DS within SAP APO to allow rough-cut planning of production, that is, to define which material a resource should produce in a particular period. In a steel plant, for example, this could be particular steel that should be rolled as soon as possible after casting.

If a sales order is entered into SAP R/3, SAP APO performs an availability check. If stock is available to cover the requirement, the quantity is confirmed. If not, a planned order is created in SAP APO to cover the requirement. The order is scheduled for the end of the relevant block in production planning, so that each production order within the block can still be moved for optimization without impinging upon the confirmed date in the sales order. The requirement quantity in the sales order can also result in multiple planned orders if several single units are required to cover the requirement.

The industry-specific optimizer takes into account orders of a certain period before the start of production. For example, it selects all planned orders in SAP APO that are in the next day's production blocks. The current status of the production orders already in production, as known from the confirmations in SAP R/3 and SAP APO, is also recorded. The planned orders are then optimized according to specific rules to determine the optimum rolling sequence (coffin-shaped) for a hot rolling strip, for example.

The materials (batches) available from the preliminary steps or that are in stock are also taken into account. This consideration is mandatory, because a rolling sequence can be optimized based only upon the properties of the physically available stock used for the production being planned. Individual production orders not yet at the production stage might also be given priority for an optimized result. In this case, a specification must indicate the extent to which these orders should be taken into account.

Once the optimization tool has determined the plan, it is imported back into SAP APO. The planned orders in SAP APO, which now mirror the determined production sequence exactly, are then converted to production orders and transferred to SAP R/3. They are released for production in SAP R/3 and passed to the MES. Production then proceeds in the MES according to the plan, and the confirmation data is recorded.

If final confirmation has occurred for a production order, the produced quantity is also booked to the stock. This means that all materials are kept in stock, even material between the production units in the production area, and are available for planning. If a material is produced outside the tolerance limits and the values mean that the material does not have to go through the next production stages or has to do so differently, planning reacts automatically. The reaction occurs because there is no planned access to the requirement in this case, and non-planned stock is available and can or must be processed into a different finished product at this stage of production. Planning looks for alternatives in the next planning run to compensate for the missing stock, and the non-planned stock is taken into account in planning and can be used as material components for other production orders.

If all production orders that belong to a sales order are complete and the stocks are available, the rest of the process such as delivery and invoicing takes place in SAP R/3.

Advantages of the method:

- Planning is integrated.
- Central planning, which leads to a higher quality of planning
- Overall visibility of current production status: all data is reflected in SAP R/3, SAP APO, and MES in the same way and differs only by extent.
- WIP material can be mapped because all material is kept in stock and therefore no WIP material exists anymore according to the traditional definition.
- Cross-plant planning is possible.

Disadvantages of the method:

- Large number of production orders in the system
- Large number of material levels
- Assignment of production orders to customer orders (n:1)

INTERFACES AND TECHNOLOGY

This section provides an overview of SAP interfaces for connecting MES. The various interfaces are discussed with their functionality and area of use.

PLANT DATA COLLECTION (PDC)

SAP provides its own interface for plant data collection (PDC): the plant data collection interface (PP-PDC). Its task is to exchange all data required for confirmations between SAP R/3 and the subsystem. The asynchronous BAPI interface transfers master data, transaction data, and production orders from SAP R/3 to an MES. The MES then enters the confirmations as time tickets or time events, which are then communicated back to SAP R/3, and the production orders updated. This approach enables real-time production-process control and a greater degree of transparency in production because a production status is available.

PRODUCTION OPTIMIZATION INTERFACE (POI)

With the production optimization interface (PP-POI), SAP provides an interface for data exchange between SAP R/3 and an optimizer system. The POI can transfer master data, such as material, BOMs, and work centers, as well as transaction data, such as planned orders and production orders, warehouse stocks, and so on, based upon integration of application link enabling (ALE) technology using intermediate documents (IDocs). The download from SAP R/3 to the subsystem is asynchronous. The optimizer system can create, change, and delete planned orders, production orders, and process orders. The data is transferred directly back to SAP R/3 using synchronous communication.

INSPECTION DATA INTERFACE (IDI)

In quality management, quality data can be transferred from an SAP system to a subsystem via the open interface inspection data interface (QM-IDI). SAP R/3 makes quality data available to the subsystem as standard values for inspection processing. Once the quality inspection is complete, the subsystem reports the results for the standard values. Communication occurs synchronously and the subsystem triggers the quality data and confirmations. Function modules in the SAP system enable this ability. With simpler measuring instruments, the connection is set up directly using various PC interfaces.

OBJECT DISCOVERY AGENT (ODA)

SAP provides two connection options for working with SCADA or process control systems. The first, SAP Object Discovery Agent (SAP ODA) is based upon the open, industry standard OPC (OLE for process control). The OPC standard was defined by the OPC foundation with different specifications, of which SAP supports OPC Data Access, the original standard. SAP also supports the second option, the OPC Events & Alarms Standard. OPC Data Access is used to read and write values to and from OPC-enabled terminals or applications in real time. The business processes can run manually or semiautomatically, with the option of user interaction. The data flow is reciprocal and synchronous. OPC Events & Alarms, however, supports alarm and event messages on request, such as malfunction messages or tracking notes.

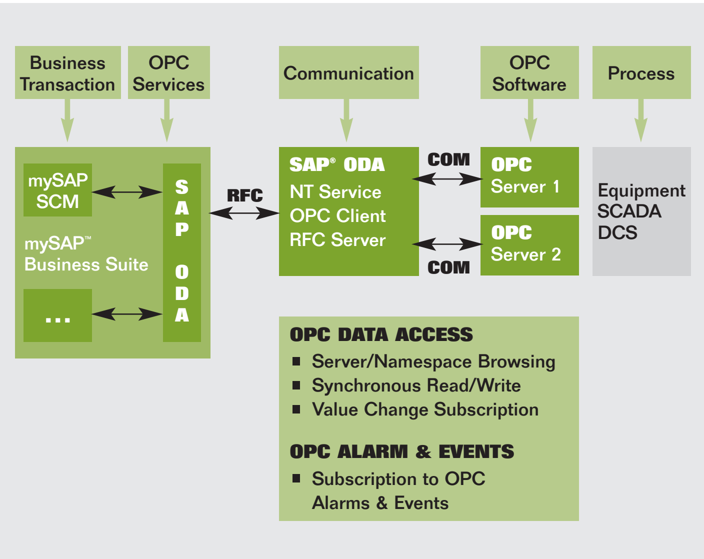

Figure 11: SAP® OPC Technology and Architecture

PROCESS CONTROL SYSTEM (PCS)

SAP's own interface, process control system (PI-PCS), is also designed for the cooperation of SCADA and process control systems with SAP R/3. It is an asynchronous interface that supports fully automated processes. It works on a foundation of messages, which means that entire process-industry control recipes can be transferred. The PCS interface does not compete with SAP ODA because each works with different communication options and therefore complement each other.

OPTIMIZER

Analogous to the PP-POI interface, the optimizer is an interface for industry-specific optimizers, an interface between SAP APO systems, and an optimizer tool. The optimizers can be trim optimizers, rolling sequencing optimizers, or various other industry-specific optimizers. From SAP APO, the optimizer system reads data such as capacities, capacity commitment, planned orders, and so on. An optimization is performed based upon this data. The optimization result is reported back to SAP APO, and a planned order that represents the optimization result is generated in SAP R/3. The planned order cannot then be changed or deleted by SAP APO; like generation, changes or deletion must occur with a BAPI or with use of the optimizer.

SAP EXCHANGE INFRASTRUCTURE (SAP XI)

With SAP Exchange Infrastructure (SAP XI) component of the SAP NetWeaver™ platform, SAP provides technology for integrating subsystems into an SAP system. This technology offers far more functions than a simple interface. SAP XI provides the design, configuration, runtime environment, and monitoring of all SAP and non-SAP interfaces. It supports current open standards such as HTTP, XML, SOAP, and many others. Based upon a business infrastructure, SAP XI consists of several components that offer various integration processes. SAP interfaces and open standards are predefined in the integration repository and integration directory, and the system landscape is mapped. The messages are physically transferred in the integration server. The logic for when and where specific messages should be transferred is also found here. The various systems are connected to the integration server with adapters. SAP differentiates between technical adapters, such as Java Message Server (JMS) or HTTP(S), other software systems such as Baan, JDE, or other SAP software partners, and industry standards such as RosettaNet, EDI or PapiNet. Data exchange using SAP XI is primarily asynchronous, but synchronous exchange is also possible.

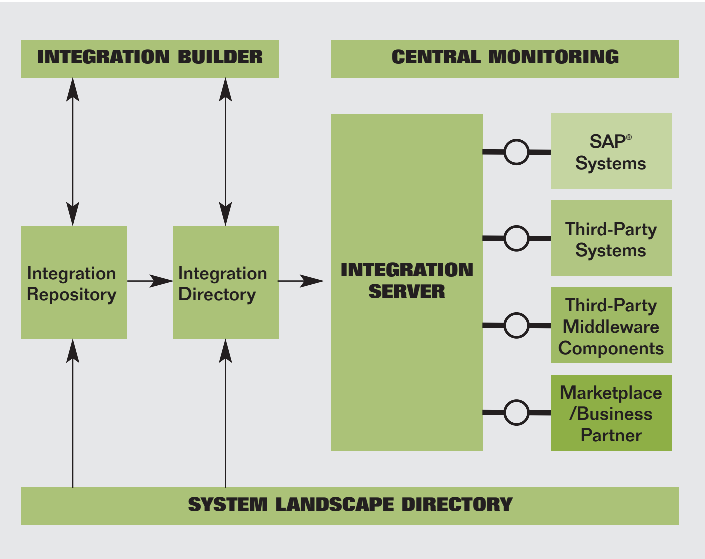

Figure 12: SAP® Exchange Infrastructure Overview

SUMMARY AND CONCLUSION

SAP's continuous provision of underlying support for the functional requirements of mill industries in its products, such as the trim sheet order and the various SAP APO enhancements, has produced a new paradigm. The new paradigm's single-level planning offers significant cost advantages and less complexity when integrating MES functionality to SAP systems.

Subsequent versions of this document will also cover the following topics:

- Practical project experiences with existing SAP interfaces and their usability for integration with MES.
- Proposals on how to use SAP XI for SAP–MES integration.
- Integration in the area of logistics execution (warehouse management, shipment, and transportation).
- The role of central master-data management in integrated scenarios.
- Integrated performance management for collecting and evaluating data from all shop floor levels to get KPIs for improving production.

GLOSSARY

ATP	available to promise
CTP	capable to promise or capable to produce
EDI	Electronic Data Interchange
ERP	enterprise resource planning
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol with SSL
JMS	Java Message Server
OLE	Object Linking and Embedding
SCADA	Supervisory Control and Data Acquisition
SSL	Secure Sockets Layer
WIP	work in progress
XML	Extensible Markup Language

50 069 657 (04/07)