28 Conclusions and Outlook

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28.1 Summary of Advanced Planning

The preceding chapters have shown the different steps of implementing an APS, starting with the analysis of a given supply chain, its redesign and subsequently modeling the supply chain from long-term to short-term decision and planning levels. The integration of all planning tasks relating to the fulfillment of customer demand will result in a superior enterprise wide and supply chain wide planning. Thereby, an APS will not only yield improvements on the three crucial factors of competitiveness, namely costs, quality, and time, but it will also allow for

- Making processes and the state of the supply chain more transparent
- Improving flexibility of the supply chain
- Revealing system constraints
- Managing the three buffer types—inventory, capacity, and time—more effectively
- Providing advanced optimization techniques to solve complex decision problems
- Computing what-if scenarios, simulating the impact of decisions in the supply chain.

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Widely available information from all over the supply chain enables the supply chain components to anticipate the demand picture at all stages of the chain, to plan the supply accordingly, to identify and resolve constraints, and to manage the buffers in the supply chain such that service level, costs, and working capital are optimized to meet the business goals. The order fulfillment processes in the supply chain become more transparent, efficient, and effective. Companies and supply chains are able to provide customers with accurate information about the order status and with alerts in the case that an unexpected event causes the delayed delivery of an order. However, before this happens a decision maker can find and check based on an APS alternative ways to fulfill the customer's order, either by a shipment from another warehouse or another production site or by offering products that might be substituted for the product originally requested. Additionally, transparent processes will reduce waste along the supply chain, because waste, e.g. resulting from excess inventories or resources with low utilization rates, will be recognized quickly and measures for its improvement may be introduced. More importantly, due to its optimization capabilities, an APS will keep waste to a minimum, right from the beginning.

With markets and customer expectations changing quickly, supply chains not only have to respond but to anticipate new trends. In some cases, this may be achieved by integrating key customers or key suppliers in the supply chain models represented by the APS. On the other hand, *flexibility* comes into play, which can be discussed along two dimensions: One is to be able to cope with changes in actual demand given the current inventory position, equipment and personnel, the other is to be able to adapt to changing markets over time (sometimes called agility, see Pfohl and Mayer 1999). An APS supports both dimensions. As an example, the ATP module can show ways of using existing inventories in the most effective manner. Also, Production Planning and Scheduling allows for the re-optimization of a new mix of orders quickly. Flexibility is further enhanced by an APS, due to a significant reduction of the frozen (firmed) horizon (as an example see Chap. 22). Midterm Master Planning should not only coordinate the decentralized decision units, but also plan for a reasonable degree of flexibility over time. Finally, APS-based ATP supports more flexible rules for allocating supply to demand and to schedule the fulfillment of customer orders.

In order to improve competitiveness, the *revelation of system constraints* is a crucial part of a continuous improvement process (see also Goldratt 1999). System constraints may be detected at different levels of the planning hierarchy. For example, midterm Master Planning will not only provide an optimal solution for a given situation, it also shows which constraints are binding, i.e. preventing a higher level of our objectives. Looking for ways to lift the system's constraints, e.g. by a more flexible employment of the workforce, will further improve competitiveness. This will give rise to defining several scenarios from which to choose. Compared with former times, defining a scenario and getting an answer is now a matter of hours, not weeks. Therefore, management and planning staff can work together more closely and effectively than before.

28.2 Further Developments of APS

Some of the above statements may still be regarded as visions. But as our case studies have shown, there are already implementations of APS in industry that are showing impressive improvements. In order to extend these success stories to a wider range of companies and supply chains, five main topics have to be addressed carefully:

- Improving modeling and solution capabilities of APS
- Ensure that the required master and transactional data is available and consistent
- Linking APS to controlling
- Extending the applicability of APS to polycentric supply chains
- Integrate APS with the automation layer of technical processes (SCADA, Supervisory Control and Data Acquisition).

28.2.1 Modeling and Solution Capabilities of APS

Although APS are around for several years, additional features are expected to be introduced in the near future. However, the standard architecture of modules most probably will remain stable. Experiences with some modules have shown that some restrictions still may exist in modeling a given (production) process adequately. Given that supply chains have to adapt to new market trends quickly, modeling should be easy to learn and fast to implement. Likewise, one should expect a similar modeling language for all modules provided by an APS vendor (unfortunately this is not always the case).

Furthermore, we experienced that not all models generated have been solvable within reasonable time limits or have not shown a satisfactory solution quality. However, minor changes in the model have improved solvability significantly. Hence, enhanced modeling capabilities and more robust solution procedures solving large problem instances are still looked for.

28.2.2 Quality of Master and Transactional Data

Models and plans are only of value if they have an impact on a supply chain's decision making and operations. This obvious statement is often ignored in practice. First of all, master and transactional data must be of high quality and reflect reality at a level of detail that is matching the intended scope and results from planning. If the level of detail is too low, the plan will not reflect the right decisions a human planner might have taken, aware of all details and based on experience. If the level of detail is too high, the model will become very complex, it might take too long to solve planning problems based on the model, and the quality of the data on which the model is based will be lower: The more details a model comprises, the higher the probability that some data element is not accurate or even wrong.

Secondly, if reality is changing faster than the total time required for data extraction, transformation and provision to create the model, the planning process and optimization time, and the approval and communication of the resulting planning decisions, the quality of the decisions will deteriorate. In this case, acceptance of the planning results and the planning system will suffer, and decision makers will use alternative tools for generating solutions like spreadsheets, where they have better control of the data and the cycle time between data collection and planning results. However, using spreadsheets usually incurs severe drawbacks like lack of data security and consistency as well as an inferior solution quality.

Along with the increasing digitalization of the world and the improving bandwidth, pervasiveness, and semantics of communication networks, we enter an age of ubiquitous information availability. This includes the space of inter- and intra-company communication networks and the space of individual communication devices, connecting planners, decision makers, production supervisors, buyers, transport personnel, managers, sales representatives, etc. every time and everywhere with other persons and systems being involved in the supply chain. This allows for new solutions to feed latest information from the actual execution processes to the planning system, updating the model and allowing for instant plan updates. Some APS vendors like SAP and E2open plan to setup APS-based cloud solutions, enabling a seamless and fast integration of all people and systems in the supply chain. User interfaces will be derived from social media systems (being the most prevalent data entry systems globally) and will support distributed entry of data and collaboration at the planning tasks at hand, e.g. Sales & Operations Planning (see Sect. 8.4).

28.2.3 Linking APS to Controlling

Today, management is more inclined to make use of tools from (the) controlling (department), like budgets or the balanced scorecard, than to rely on APS. Hence, greater emphasis should be placed on *linking APS modules with controlling*, either by linking decision models to key performance indicators or—even better—to incorporate APS into the tool set of controlling.

A good example for the tight integration of controlling processes and supply chain planning are the yearly budgeting process and the demand and master planning processes (sales & operations planning process). Both create an anticipated picture of future customer demand. The former to determine the required financial means to run the business and to allocate budgets to cost centers. The latter to prepare the supply chain for delivering the future demand, to detect limiting constraints, to set a foundation for order promising (ATP). Budgeting is normally done yearly, sales & operations planning monthly or even weekly.

Although both process areas—budgeting and S&OP—might use the same demand plan, this is not always desired. There might be scenarios where not all details of the operational S&OP plan shall be shared with public, whereas the financial budget plan must be made public, at least in an aggregated format for listed corporations. In any case, the operational plan for supply chain purposes and the public plan for budgeting purposes should be aligned as close as possible and the deviation between the two plans should be made explicit, managed and carefully tracked.

A second example of the tight integration of controlling and APS concerns performance management. As described in the previous section APS integrate a large amount of master data and transactional data from customer processes, production processes, transportation, warehousing, procurement, etc. Thus, APS are a perfect source for data that might be used to calculate performance metrics like process times, process costs, inventory, service levels. These operational metrics are of high relevance to setup controlling tools like a Balanced Scorecard. A Balanced Scorecard includes further metrics from finance, customer, other processes, and learning and people perspective. Thus, it creates a 360° view of the performance of a company, that might help in a supply chain context to derive decisions.

28.2.4 Extending APS to Polycentric Supply Chains

So far, APS are best suited for supply chains with centralized control, i.e. mainly for intra-organizational supply chains. Although information exchange, in principle, is no problem for APS implemented in an inter-organizational supply chain, the willingness to operate on the basis of "open books" (e.g. regarding costs and available capacities) cannot always be assumed. Although collaborative planning (Chap. 14) has been introduced, the knowledge of how to adapt plans generated in different planning domains is still in its infancy.

One industry sector is currently leading the development of inter-organizational supply chain management: the electronics industry, mainly large volume consumer electronics OEMs, contract manufacturers, and the corresponding components suppliers:

- OEMs like Apple, Samsung, Microsoft, and Hewlett-Packard, own the brand and the product design and are responsible for marketing and distributing the finished goods via electronics retailers or their own outlet stores.
- Contract manufacturers or specialized assembly plants of the OEMs act as integrators for the component supply chains, synchronizing the demand for assembly, the component supply, and the schedule for the introduction of new product revisions.
- The component suppliers integrate closely into the assembly and distribution stages of the supply chain, synchronizing their own component assembly with the assembly schedule of the contract manufacturer or OEM assembly plants.

In the electronics industry sector demand and supply are changing fast, due to the dynamics in the network (many active players being highly interconnected) and the rapid innovation rate and new product introduction. To balance demand and supply, APS and the corresponding planning processes must extend across legal entities, represent customer demand, inventories and supply capabilities of all sites in the network, and come up with an inter-organizational demand and supply plan.

Typical features in the electronics supply chain planning processes are daily demand commits, feasible production, procurement and transportation plans (rough cut), and optimized air vs. sea transportation. These regular demand and supply updates incorporate the complete electronics supply chain including retailers, OEMs, contract manufacturers, components suppliers and logistics service providers (Karevaska and Kilger 2013).

Great efforts are currently undertaken by APS vendors to match planning issues facing industry sectors with the capabilities of an APS, e.g. inter-organizational planning approaches as discussed above for the electronics industry sector, the issue of safety stocks in a multi-level supply chain, and the issue of incorporating lot-sizing (rules) at different (hierarchical) planning levels. An additional strategy toward a better fit is to devise specific APS modules focusing on the specific needs of certain industry sectors. A further trend addresses the combination of decentralized control on the detailed level with centralized control on a more aggregated level of the supply chain. As Daganzo (2003) shows, decentralized control in a supply chain may lead to a good solution close to the optimum, if certain rules are defined and observed by supply chain partners. These rules might for instance level production quantities at one process, ensuring certain bounds for the consumed and produced quantities upstream and downstream in the supply chain, respectively. Many of these rules have been developed in the context of Lean Manufacturing (see Womack and Jones 2003 for an overview). Some APS vendors like SAP for instance started initiatives to extend their SCM suites (including the APS).

28.2.5 Integration of APS with the Automation Layer of Technical Processes

Under the umbrellas of large research initiatives like Internet of Things in the U.S. and Industrie 4.0 in Germany the technical platforms for production, transportation, warehousing, and distribution processes are changing fundamentally. The essence of this change are enhanced capabilities of technical equipment, parts, assemblies, finished goods, transport units, etc. to connect to the Internet and to form integrated networks that can be controlled by software layers like automation software, manufacturing execution systems, transactional systems like ERP systems, and APS.

In some industry sectors, that require fast reaction to demand and supply changes, fast product change overs, and low cost of goods sold like the fresh milk industry, new scenarios of integrating APS with the automation layer of technical processes are emerging. Consider a fresh milk production facility, consisting of the raw milk storage, multiple filling and packaging lines, and the cold store buffering the finished goods before they are picked up by retailers for distribution. A typical fresh milk production site is responsible for 30–80 SKUs (different packaging sizes and styles, different raw milk qualities, different fat grades, lactose free vs. regular, different brands and labels). This portfolio has to be produced every day. Stock-outs lead to loss in sales for the milk producer and for the retailers, as consumers will change to another supermarket if fresh milk is not available. Therefore, the filling and packaging lines usually have a higher capacity than required to fulfill the total demand of a day. The constraining factor is the cold store, that can hold only a limited volume of SKUs (running a cold store is energy-intensive and therefore produces high costs). As a consequence, if the filling and packaging lines are producing at full speed, the cold store will be completely filled after a couple of hours.

By integrating the automation layer of the machines in the filling and packaging lines with the APS of the production site, the speed and the product mix of the lines can be directly controlled by the APS, synchronizing the distribution and replenishment plan of the retailers with the production plan and the production execution.

As the Internet of Things and Industrie 4.0 initiatives are driven forward, we expect further scenarios to emerge where the automation layer of technical processes will be directly integrated with an APS. This integration will plug the technical equipment of manufacturing, transportation, warehousing, and distribution directly into a supply chain planning layer, allowing for immediate transformation of supply plans into execution.

28.3 Management of Change Aspects

In order to use APS effectively, managers and employees must have *special training*, enabling them to interpret solutions, recognize interactions with other parts of the supply chain, set up scenarios and react to alerts appropriately. In addition to project management, the mastery of change management and the basics of computer science, consultants now must have knowledge and experience in generating adequate models of the supply chain for the different modules of an APS. These models, neither being too detailed nor too rough, have to support decision making and must be solvable with reasonable computational efforts. Inadequate models may even deteriorate the position of the supply chain instead of improving it.

Introducing an APS is not just adding another software package to those already existing in a company. On the contrary, it will replace many individual software solutions formerly “owned” by individual employees. Also, some types of decisions, which formerly required several employees, like creating a detailed schedule for the shop floor, will now be made (almost) automatically. Consequently, some of the employees will have to change to other positions, which may result in some resistance to change. On the other hand, optimization capabilities of APS will yield better plans than before with the additional option of checking alternatives interactively, thus giving those involved a greater satisfaction.

Last but not least, one should bear in mind that introducing an APS changes the way an organization or supply chain works. The definition of processes fulfilling the needs of different market segments will have to be reflected within the organizational structure. For legally separated firms or profit centers within a single firm covering only a portion of a given process, an effective reward system has to be installed in order to achieve the best solution for a supply chain as a whole and not get trapped in isolated sub-optima (see e.g. Fleischmann 1999).

Recent reports on APS implementation projects have shown that the above recommendations should be taken seriously. Some APS users may have observed a discrepancy between their expectations, the vendors' promises and the capabilities of consultants as well as the APS software. In order that all parties involved get a realistic view, prototyping seems to be a good choice. Also, great visions should not be approached in one step, instead a stepwise introduction of SCM ideas and software support seems more appropriate.

28.4 Scope of Supply Chain Management

In recent years, several empirical studies have been conducted aiming at the revelation of key success factors for an effective, superior supply chain. As one may expect, a great number of factors have been proposed and tested. Two noteworthy factors, which have been found to be significant, are *"… structural elements such as having an integrated information system, and behavioral relationship building elements such as trust and commitment … "* (Jayaram et al. 2004). These findings are in accordance with our recommendations throughout this book.

There are different ways to set up supply chains, each capable of achieving specific strategic and operational goals of the company. Redesign of organizations and processes builds on strategic objectives as well as on enabling information technology. Performance Management has to ensure transparency in operational control information, but also provides tools and methods to lead all employees to achieving the strategic goals. Innovative information technology—like APS—provide new ways of working, accelerating the business, and thus creating sources of strategic impact ("Business drives IT & IT drives Business"). Change management is the binding and bonding element in making the business transformation sustainable, by addressing skills and capabilities, but also behavior and the value system of the people.

With regard to future developments of SCM as a whole, one can expect that it will not only concentrate on the order fulfillment process alone, but will incorporate neighboring processes like product life cycle management, automation of technical processes, and financial management.

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