Supply Chain Management and Advanced Planning in the Process Industries

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Summary. Advanced Planning Systems decompose Supply Chain Management into long-term, mid-term, and short-term planning tasks. In this paper, we outline these tasks and reference application-oriented state-of-the-art solution approaches with regard to the process industries.

1 Overview

In the recent past, Advanced Planning Systems (APS) have been developed to support Supply Chain Management (SCM). For each section of the supply chain, i.e., procurement, production, distribution, and sales, APS offer support for long-term, mid-term, and short-term planning while always taking into account limited availability of resources. Planning is supported by appropriate demand forecasts (cf. [11]). Long-term planning concerns the product program, the decoupling points, the cooperations with suppliers, the plant locations, the production systems, and the distribution structure. Mid-term planning synchronizes the material flows along the supply chain. Short-term planning is performed for each section of the supply chain individually and concerns order quantities, production schedules, warehouse replenishment, as well as order acceptance and fulfillment. For a general definition of these planning tasks see [14].

In this paper, we examine the planning tasks with regard to the process industries (e.g. chemical, pharmaceutical, food and beverages, or metal casting industries). In those industries, value is added to materials through the successive execution of chemical or physical transformation processes such as heating, filtration, or mixing (cf. [3]). Important peculiarities of process industries that have to be taken into account by SCM are discussed in [1, 16, 23, 35]. In the following, we concentrate on the related planning tasks, i.e., choice of product program, network design, selection of production mode, design of plant layout, mid-term planning, and short-term production planning.

In the remainder of this paper, we outline these planning tasks and briefly review state-of-the-art methods for long-term (cf. Section 2), mid-term (cf. Section 3), and short-term (cf. Section 4) SCM in the process industries. Comprehensive literature

surveys about some of those planning tasks are provided by [23, 25, 32, 33]. A review addressing rework can be found in [13].

2 Long-Term Planning

The planning horizon considered in long-term planning typically comprises three to ten years. An important decision to be made is the choice of the **product program**. In the process industries, each new product generally has to pass a series of extensive regulatory tests. Product program decisions have to take into account the uncertainty that one of these tests fails which prohibits the product from entering the market. The planning problem therefore consists in choosing a set of candidate products and a schedule for their development such that constraints on the development sequence and on the scarcity of research resources are met and the expected net present value is maximized.

Many solution approaches are based on mixed-integer linear programming. A review is contained in [27]. These approaches mainly differ in the way the research resources are considered. In [31], one such model is applied to an industrial case study. Other approaches make use of simulation models. [4] simulate the evolution over time of the new poduct development process in order to assess product candidates. In the genetic algorithm presented by [5] product development sequences for a set of candidate products are evaluated by simulation.

Network design deals with the determination of plant locations and the distribution structure. A review of solution approaches can be found in [37]. Real-world applications are discussed in [24] and [38].

Furthermore, continuous, batch, or some hybrid **production mode** has to be chosen (cf. also Section 4): In continuous production mode, material flows are continuous. Batch production mode is characterized by discontinuous material flows. In practice, the choice of the production mode is either predetermined or strongly influenced by the types and volumes of products to be produced. For instance, batch production mode is typical for the production of small volumes of specialty chemicals.

Eventually, the **plant layout** has to be established. The problem is to determine the location and orientation of production equipment items (i.e., processing units and storage facilities) such that total construction and operational cost is minimized. Production equipment items may not pairwise overlap, and safety distances between them have to be observed. For a review of solution approaches we refer to [21]. Sometimes, the number and size of or the routing of pipes between the production equipment items have to be determined as well (cf. [12, 21]).

3 Mid-Term Planning

The goal of **mid-term planning** is an efficient utilization of the production, storage, and transportation facilities determined by the long-term planning. The planning horizon has to cover at least one seasonal cycle to be able to balance all demand peaks and is divided into periods with a length of a week up to a month. Decisions have to be made on purchasing, production, and transportation quantities for final