240f Coordinating Production and Transport Scheduling in Scm through Rigorous and Heuristic-Based Methods

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The recent boost in competitiveness for customers and new products, the development of more complex and tightly integrated plants, and the relaxations in restrictions of global trade have lead to an increasing interest in the development of efficient optimization techniques not only focused on a plant level but also extended to the entire Supply Chain (SC). Supply Chain Management (SCM) represents a very challenging problem that is focused on the effective combination of strategies and tools to integrate all the entities involved in the SC (suppliers, production plants, customers, markets, etc.). Depending on the desired detailed level and the time horizon considered, this problem can be addressed at different interrelated and hierarchical levels (strategic, tactical and operational). Most of the work reported in the literature deals with the SCM problem from a strategic or tactical point of view to optimally configure or manage the system according to some economic objective. However, from the operational perspective the detailed production scheduling and distribution requirements to different sites have been extensively analyzed but generally decoupled, assuming little or no coordination. This problem simplification usually arises because of the high complexity and the large number of decisions to be made at this lowest level.

For short-term production scheduling, alternative methodologies and problem statements with different considerations have been proposed in the literature. Most of these works rely on mathematical programming approaches based on discrete or continuous-time representations (Shah, 1998; Kallrath, 2002). Although these rigorous methods are able to guarantee the optimality of the solution, their applicability is currently restricted to quite small cases due to the inherent combinatorial nature of scheduling problems. To overcome this limitation, a wide variety of heuristic and rule-based procedures have been developed aiming at providing good schedules to large scale problems in a reasonable time (Pinedo, 2001). Commonly, the production schedule is developed assuming an instantaneous delivery of goods, thus ignoring the transport time between production locations in the SC.

On the other hand, the transport scheduling problem, usually referred to as pickup and delivery problem, has centered significant attention in the area of Operations Research, and numerous exact and heuristic algorithms have been proposed for their solution (Hillier and Lieberman, 2001). Transport constitutes a central activity to be considered within any multi-site system. The vehicle routing problem in which a number of vehicles available in a site of the SC have to serve a set of geographically dispersed locations, can be identified in most of the sites. Assignment, routing and timing decisions have to be made aiming at optimizing a specified objective function. Transport problems have been mainly focused on the individual and geographical aspects of the transport task to reduce the delivery cost. Extensions of the problem introducing time windows within which demands have to be served, vehicle capacity restrictions and minimum distances between the locations can also be found (Marinakis and Migdalas, 2002; Dondo et al., 2003).

The decoupled production and distribution operations rely on finished goods inventory to buffer both operations from each other. However, inventory costs and the trend to operate in a just-in-time manner are putting pressure on firms to reduce inventories in their distribution chain. Besides this, additional features need to be considered when dealing with SCM in the chemical process industry. Particularly, complex temporal and capacity interdependencies arising between production processes in a SC environment due to load sizes, travel time allowances, and service time windows, place important constraints to be taken into account; the total amount of a product to be delivered in any time point cannot exceed the amount available as implied by the production schedule first determined. Therefore, the efficient coordination of production and distribution systems becomes a challenging problem to be further considered, with an increasing interest as companies move towards into higher collaborative and competitive environments.

Focused on the operational level of SCM, this work addresses the coordination of detailed short-term production and transport scheduling problems from the perspective of a production plant of a multi-site system that owns, or leases on a long-term basis, a fleet of vehicles for its logistic needs. Particularly, the scenario considered concerns a multiproduct batch plant, which produces a number of products over time that have to be distributed to a number of delivery centers or retail outlets. Both production and transport problems are modeled as detailed scheduling problems, where the terms of transport orders, routes and vehicles are used for transport scheduling, similarly to the terms of demands, batches and units used in the production scheduling paradigm. The transport time accounts for the combination of a travel time, given by the speed of the vehicle associated with that route and the distance to be covered, a discharge time depending on the amount of material delivered, and a fixed stop time. The problem consists of identifying the detailed production (number of batches to be produced, assignment of units to production stages, sequencing and timing) and transport schedules (loads, assignment of vehicles to transport orders, routing and timing), so as to optimize some established criterion, while managing the inventory profiles, the material flows and temporal interdependencies between production and delivery centers. Although it is difficult to define the optimality concept in terms of a single objective to efficiently take into account all the features of the problem, different criteria, from time considerations (delivery times to meet the due dates) to economical measures (cost of production setups, transport and inventory), are considered and analyzed for the integrated production and transport schedule.

Two alternative modeling approaches that rely on a rigorous MILP formulation and a heuristic-based open framework are presented. The mathematical formulation is based on a continuous-time representation, where the assignment and sequencing decision variables are managed independently. Concerning the heuristic framework, common dispatching rules are used to address the production problem, while an order-based heuristic algorithm has been developed for transport scheduling. Even a simple SC configuration leads to a large-scale optimization problem to which obtaining the optimal production and transport schedules with reasonable CPU time becomes quite difficult. The aptitude of both methods for generating good schedules in a limited time is evaluated and compared through different examples. The results obtained show the applicability of both modeling frameworks and illustrate the benefits of developing solution techniques coupling both the accuracy of mathematical approaches and the flexibility of heuristic-based methods to efficiently address the complexity of a real-world problem. The importance of coordinating both activities in a SC environment is also highlighted.

References

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