Aspects and Views on Mathematical Optimization in Logistics in the Chemical Industry

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Abstract. In large chemical companies, traffic logistics and supply chain logistics contain many decision problems which are suitable to be solved by mathematical optimization. The objectives are to exploit resources (traffic infrastructure such as roads and rail lines, production equipment) in a cost optimal way and to maximize profit.
We present two cases: optimal sequences of rail cars in trains visiting various plants in a large company complex, and production and distribution planning. Finally, we discuss the importance of data structure and the consequences of differences between the "booking world" view of systems such as SAP and the "physical world" mapped into mathematical optimization models.

1 Introduction

Mathematical optimization in logistics is a wide field, *cf.* the many contributions in *these* Dagstuhl proceedings. Therefore, in this contribution, we discuss only a few aspects related to our practical experience. In Section 2 we provide two application examples: one related to traffic logistics, another one related to supply chain logistics. Both require proper interfacing to company wide data bases. Therefore, in Section 3 we discuss the role of data in SAP and SAP APO, followed by some conclusions in Section 4.

2 Logistics Problems

A large company such as BASF SE and its subsidiaries has, of course, its own, inhouse logistics division supporting various problems occurring in the company's logistics. There seem to be at least two camps of logistic people focussing on traffic logistics and supply chain logistics. Traffic logistics involves the internal company-wide transport infrastructure (roads, train lines), equipment, *e.g.*, truck loading stations, trains, waggons, storage tanks, etc., and the definition of processes related to traffic. Supply chain logistics has a strong focus on the definition of processes connected to the supply chain and the supply network, and

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the material flow through the supply chain and supply network (supply chain planning, production planning, scheduling). Projects leading to mathematical optimization are rather the exception than the rule. However, if they do, they are solved in interdisciplinary projects teams involving the clients (often non-mathematicians, non-academics), IT-Support (strong focus on standardization and maintenance), logistics departments, and the inhouse scientific computing group.

2.1 Example: Traffic Logistic

As an example of inhouse traffic logistics we mention the joint BMBF project "Zeitkritische Ablaufbergoptimierung in Rangierbahnhöfen" (2004-2007) with R. Hansmann and U. Zimmermann (TU Braunschweig) and the BASF logistics department. As described in Hansmann & Zimmermann (2008), we considered up to 600 incoming railcars/day, up to 5 tracks for sorting, and between 3 and 20 railcars per outgoing train. Two solution approaches have been developed. The first one applies to shunting yard tracks with unconstrained length and implements a tailor-made algorithm based on some special partitioning of integer sequences running in linear time. The second one handles shunting yard tracks with constrained length and is based on a mixed integer model which may be solved by professional solvers but requires much more computing time. Among the benefits were reductions of the number of the outgoing train splits on the BASF railway network and reductions of the time for sorting trains on the BASF hump yard. The mathematical solution led to smoother operations and turned out to be superior to rule-based sorting. The tailor made algorithm is online suitable (it solves the problem in seconds) and allows quick reactive runs by the dispatcher. The user can, however, only harvest these benefits, if the system is properly integrated into BASF's IT landscape, which, for instance, may be achieved by embedding the algorithm into Siemens's Monitoring and Control System VICOS used by the client.

2.2 Example: Supply Chain Logistics

Supply chain logistics – instead of the more common term *supply chain* we rather prefer and use term *supply network* because this covers better the more complicated topology we often encounter in the chemical industry – deals with the material flow over the whole supply chain. Probably, twenty or thirty years ago this would have been called production planning although it adds elements of distribution, sales and stock planning, and may involve scheduling as well. Detailed multi-site and multi-product supply network examples with typical feature present in the process industry such as multi-stage batch and campaign production exploiting multi-purpose reactors are provided in Kallrath (1995), Kallrath & Wilson (1997), Timpe & Kallrath (2000), and Kallrath (2005). Supply chain logistics can also involve the simultaneous optimization of supply chain flow and the underlying supply chain design; *cf.* Kallrath (2009). Over the years, due to more sites and additional details, these examples grow in size and mathematical complexity to problems with several hundred thousand variables and constraints. But even more important became the development of proper interfaces to company wide data basis such as SAP or SAP APO – with a detailed example provided in Kallrath (2005).

3 The Role of Data and Connection to SAP Systems

3.1 Data Structure and Constraints related to the IT Landscape

Companies have developed integrated IT systems which store most data needed in logistics in transaction based systems such as SAP, SAP R3, SAP APO, and others. These systems come with *Advanced Planning Solution* modules. For a discussion of such standard solution versus see tailor-made solutions see Kallrath & Maindl (2006). If tailor-made solutions are preferred, they have to be connected to such company wide data systems, which requires data mapping and conversion and leads to interfacing problems discussed in the next section. While in the past mathematical optimization projects had few IT aspects, now the IT part can be come overwhelming if not even dominant. Therefore, it becomes important to know about the soft skills to run and lead major IT projects as described by Köhler & Oswald (2009). Nevertheless, it is also important that it is made cristal clear that mathematical optimization projects do not have the inner dynamics of IT projects. Very often, the major threshold to overcome is the initial model development and prototyping followed by a more shallow phase involving fine tuning and increasing the stability of the solution procedure.

3.2 "Booking World" versus "Physical World"

The challenges to connect optimization to systems such as SAP or SAP APO are related to the distinction introduced by Hecker (2009) between the "Booking World" (which refers to the production and logistics process as seen from an SAP APO point of view utilization) and the "Physical World" (which refers to the same process, but from the automated – mathematical optimization based – planning point of view. Differences between both worlds are not a specific problem of SAP APO, but they are of a more general nature possibly connected to incomplete physical representation, numerical incompatibilities and soft versus hard interpretation of input data, virtual objects in SAP APO which do not exist in reality view, and that data retrieved from an ERP Systems ("Booking World") cannot be used for tailor-made optimization ("Physical World") without intervention.

The lesson to be learned is that there is nothing like *the* interface for communication between SAP APO and tailor-made optimization model

4 Conclusions

From a modeling and algorithmic point of view, mathematical optimization is technically well suited to be used in quantitative logistics problems and to support decision making. Ideally, it should not replace decisions, but deliver optimal, or at least valid suggestions within a given framework. Ideally, it does not replace human intuition and constructiveness, but identifies limiting constraints, evaluates proposals quantitatively and fast, and increases transparency of the business. However, the current trend in company IT structures with its strong focus on centralization, standardization and automation, may lead to situations where the individual planner has limited degrees of freedom to deviate from these automated suggestions. Therefore, given the complexity of real world logistics problems and keeping an eye on the acceptance level we stress that the individual planner and decision taker has full control over the planning tool, and is able to change and to set various control parameters.

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