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# A mixed integer linear programming model applied in barge planning for Omya

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ABSTRACT

This article presents a mathematical model for barge transport planning on the river Rhine, which is part of a decision support system (DSS) recently taken into use by the Swiss company Omya. The system is operated by Omya's regional office in Cologne, Germany, responsible for distribution planning at the regional distribution center (RDC) in Moerdijk, the Netherlands. The distribution planning is a vital part of supply chain management of Omya's production of Norwegian high quality calcium carbonate slurry, supplied to European paper manufacturers. The DSS operates within a vendor managed inventory (VMI) setting, where the customer inventories are monitored by Omya, who decides upon the refilling days and quantities delivered by barges. The barge planning problem falls into the category of inventory routing problems (IRP) and is further characterized with multiple products, heterogeneous fleet with availability restrictions (the fleet is owned by third party), vehicle compartments, dependency of barge capacity on water-level, multiple customer visits, bounded customer inventories and rolling planning horizon. There are additional modelling details which had to be considered to make it possible to employ the model in practice at a sufficient level of detail. To the best of our knowledge, we have not been able to find similar models covering all these aspects in barge planning. This article presents the developed mixed-integer programming model and discusses practical experience with its solution. Briefly, it also puts the model into the context of the entire business case of value chain optimization in Omya.



## 1. Introduction

The barge transport planning in Omya, which is the main focus of this article, is the last stage of a multi-echelon logistic chain [1,2]. We start with a top-down description of the chain, since it gives an important perspective on the barge planning problem.

The Omya calcium carbonate slurry production in Norway consists of about 20 variants that are produced at one single plant, Omya Hustadmarmor (HM), located close to the town Molde on the west coast (refer to Fig. 1). The main raw material for the production of these slurry products is marble stone supplied from one major quarry located in the north of the country (Brønnøy) and some local quarries located close to Molde. The factory has a yearly production of approximately 3 million metric tons.

Omya Hustadmarmor is the biggest of around 120 chemical plants within the Omya company. The calcium carbonate slurry, which is produced here, is used as an add-on to make paper more shiny. The 20 different variants regulate how shiny the paper becomes—from small to high. In general, a higher degree of shininess costs more.

Nearly half of the quantities produced at HM are supplied to German and Dutch paper-mill factories located close to the Rhine and Maas rivers. Serving these customers involves ship transport from HM to the company-owned tank farms (RDCs) located in Emden (Germany) and Moerdijk (Holland)—see Fig. 1.

Each tank farm contains roughly 14 days of demand for allocated customers. The tank farm in Emden, is the biggest, containing around 40 tanks with a total capacity of 60,000 tons of slurry. Normally, around 40,000 tons of this capacity is utilized. If unexpected demand changes occur, a tank allocation system (also a part of the DSS portfolio) is used for tank reallocation.

This transport utilizes 12 heterogeneous chemical tank vessels (ranging from 5000 to 18,000 dwt) owned by Utkilen AS; a Norwegian broker. Serving end customers (the last stage of the multi-echelon transport system) involves river transport by 12

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**Fig. 1.** A sketch of the model geography, including location of plants, tanks and relevant routes.

heterogeneous special-equipped barges (ranging from 800 to 3000 dwt) owned by Wijgula AG (Germany). HM is responsible for the planning of the outbound ship transport and the tank farm management at Moerdijk and Emden, while the office in Cologne is responsible for outbound logistics from the tank farms to end customers involving barge transport. The other half of the produced slurry at HM is supplied to paper-mill factories located in the United Kingdom, Sweden and Finland.

Transportation costs per unit are significantly lower for large ships than for small ships, but their use increases planning complexity and creates problems in production in HM due to limited tank farm capacities.

The production facility in HM consists of production lines that can be switched to production of different variants of the slurry. Switching of production leads to extra costs, given by loss of production capacity due to set-up times and extra (double) production time caused by quality problems. It is not possible to maintain substantial stocks of the finished products at the factory, due to the limited available storage capacities, and also due to quality considerations given by the nature of the products. Production is in this case directly linked to distribution with a short time-lag.

In daily operations the planner at HM has to (1) decide which vessel should depart on which day for which tank farm, and (2) decide what mix of products[1] each vessel should carry. From the above, it should be clear that the main challenges in this planning are to utilize large vessels in the outbound sea transport and produce large production lots with few changeovers between slurries. Product quality aspects, demand variations and tank farm limitations make this planning highly complex. Due to the practical material requirements planning (MRP) logic utilized in the supply chain management of HM/Omya, it is evident that the agent in charge, the logistic department at HM is highly dependent on predictable (reliable) barge plans from the logistic department in Cologne.

Traditionally the Omya logistic planning has been short-termed and so-called “reorder point oriented” where the main actors in the supply chain management (logistic managers, production planners, different transport operators, RDC managers) typically have spent most of their time communicating and trying to reach agreements on how to handle reorder points and sudden changes caused by delayed vessels, production problems, changed customer orders or other “events” in the value chain.

Throughout the period 2003–2006 the logistic department at HM succeeded in changing their logistic philosophy in sea-transport to a longer term planning system, where demand for different products at different RDCs (e.g. Moerdijk and Emden) was predicted by formal methodologies and safety stocks are calculated based on forecast errors and predefined customer service levels (fill-rates). The forecast and safety stock data are utilized as an input to an advanced ship-planning model that operates on a 4-week rolling planning horizon.

Implementation of the ship-planning model brought total yearly cost savings of about NOK 90 million for the company or about five percent of the company costs. This saving arose from utilization of (much) larger and cost-effective chemical tank vessels in the transportation, substantial improvements in more efficient production planning (reduced number of changeovers in production) and improved maintenance policy. The project also reported positive environmental impacts due to substantial $CO_2$ and $NO_X$ emission reductions. The ship planning project in HM entered the finals in the 2006 Franz Edelmann award. [3].

The ship planning model, as indicated above, provided substantial efficiency improvements. However, its main contribution was related to paper factories within the Scandinavian region where intermodality was not present. On the European mainland, the slurry must be transported (mainly) by barges on European waterways. Hence, in order to achieve similar efficiency improvements on these parts of the value chain, a barge planning system became necessary. The model reported on in this article, solves such a task partly. The obvious answer would be an integrated model involving all parts of the value chain, but model complexity and model size as well as organizational challenges have so far prevented such a full scale optimization implementation. However, the company has realized substantial extra savings, at the same inducing better structural understanding in the organization.

Generally, Omya’s present logistics strategy targets 100% customer delivery service, maximal ship size as well as maximal use of direct transportation (i.e. deliveries to a single plant by each boat).

## 2. Motivation

The barge planning system for the Omya office in Cologne is a follow-up project of the ship planning system at HM. The main motivation for this project has been to adopt the operations research methodology used in the HM ship planning system to barge planning at Cologne. The tank farm in Moerdijk is the plant where the inbound sea transport and outbound barge transport meet. The transports must be very well synchronized, otherwise stock-out or demurrage can occur. The main idea of the DSS and the barge planning model is to achieve – together with the ship-planning tool – a consistent logistic system based on the following MRP logic:

(i) First the Omya Cologne office forecast the customer demand and calculate the necessary safety stock at the customer inventories.
(ii) The calculation under (i) is utilized as input in the presented mathematical model for barge transport planning, operated with a 4 week planning rolling horizon.
(iii) The output of the barge planning at (ii) is communicated to the logistic department at HM to be utilized as input in the ship planning system as presented in [3] and mentioned above.

[1] That is, what combinations of the 20 variants should be filled into the barge tanks.