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A COMBINED SIMULATION OPTIMIZATION FRAMEWORK TO IMPROVE LOGISTICS PROCESSES IN THE PRODUCTION OF SPECIALTY CHEMICALS

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ABSTRACT

The chemical industry is experiencing shifts in market conditions, leading to an increasing need for fast and individual-engineered chemicals. This trend causes a change from mass production to the production of small, demand-driven quantities. This results in various variants and container types, requiring efficient logistics management to handle the complexity. A methodical framework should enable the user to fulfill the specific requirements of the logistics processes and thus make the complex planning manageable. In particular, supply and disposal methods and container management are under special consideration. Therefore, a simulation and optimization framework is developed. First, the motivation of the research project is presented. Afterward, a framework for planning logistics processes is designed, consisting of data preparation, mathematical optimization, and simulation.

1 INTRODUCTION AND MOTIVATION

The chemical industry is one of the most relevant process industries for human life. Research and technological progress in this industry has influenced people's living conditions. However, the chemical-pharmaceutical industry in Europe is transforming. Due to rising costs and more affordable production conditions in emerging markets, high-wage countries like Germany are changing their view from a long-term availability of products to specified and application-oriented products called specialty chemicals. (Bornemann-Pfeiffer et al. 2021) This leads to the individualization of chemicals and changes in customer demand behavior, causing a high degree of product differentiation, lower production volumes, and a wide variety of containers (Kiefer et al. 2023). The different production orders, including the respective requirements, lead to a high logistics complexity. These different production orders significantly affect the selected supply type of production, where a distinction is made between a supply using containers and a supply through pipelines and the associated storage of the materials in tanks. Flexible logistics processes are necessary to manage this complexity, requiring a planned and coordinated approach. Therefore, a methodical framework will be developed to support planning logistics processes for the supply and disposal of the production, considering efficiency and sustainability.

2 METHODOLOGY

Various requirements must be considered when planning the supply and disposal of the production of specialty chemicals, for example, the demand for materials. The requirements caused by the materials and the complex interdependencies of the overall production system make logistics planning with a complete representation of a real-world system impossible. Therefore, a reduction of the complexity of the model must be accomplished using simplifications, which can be, for example, assumptions or the separation into individual models. In operations research, optimization and simulation methods are mainly used for planning processes. The optimization enables the determination of an optimal parameterization, and the

simulation investigates complex interdependencies and stochastic influences. (Domschke et al. 2015) Based on the above-identified problem, a combined simulation optimization framework is developed to support planning logistics processes for the supply and disposal of the production, including container management. Therefore, the mathematical optimization determines which raw materials should be available for production using containers and which are stored in tanks and available for production through pipelines. These optimization results provide the optimal utilization of tanks based on a time period that can be individually adapted for each use case. Afterward, the results obtained can be implemented as input parameters in the simulation, which validates the feasibility. In the context of the chemical industry, this is particularly important since raw materials not selected for the tanks must be made available for production with a container. These materials may require more containers despite a smaller quantity than the raw materials in the tank because of special requirements. This, in turn, significantly impacts container management, including cleaning. Thus, it is necessary to check whether production can be realized with the given resources based on the results determined by the optimization. The developed framework enables users to determine the optimized tank occupancy depending on the production orders and the resulting influences on container management. For example, the ideal number of containers in the container cycle. Accordingly, the methodical framework increases the efficiency and sustainability of logistics processes. Figure 1 shows the linkage of the two methods combined with data preparation performed in advance.

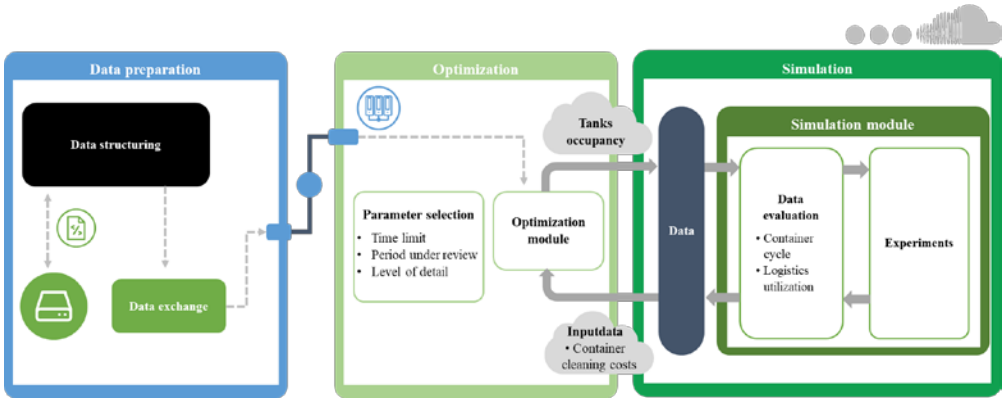

Figure 1: The conceptual structure of the methodological framework.

3 CONCLUSION AND OUTLOOK

This research project aims to improve the planning of logistics processes in producing specialty chemicals. Due to product differentiation and the resulting variety of container types, there is a particular focus on container management and the associated supply type of production. For this purpose, a combined simulation optimization framework is developed, which, in addition to the planning of the tank's occupancy, also includes the planning of the container management. An additionally developed procedure model will guarantee adaptability for the users of this methodology. The first test results already show an added value of this procedure. However, to confirm this scientifically, verification and validation of the developed methods will be carried out in the next step and applied based on a real-world application problem.

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