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Integrating Mathematical and Simulation Approach for Optimizing Production and Distribution Planning With Lateral Transshipment in a Supply Chain

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ABSTRACT

Supply chain planning aims to maximize the chain's profit and find an effective way to integrate production and distribution. Mathematical and simulation-based optimizations are two common disciplines. This study integrates both of them together to consolidate their advantages. A mathematical model is formulated to find an optimal production-distribution plan. Then, the result is fed into a simulation model operating under uncertainty to verify the feasibility of the plan. The integrated approach tries to find a feasible plan that satisfies both required customer service level and makespan limitation where safety stock is used to hedge against uncertainties, and lateral transshipment is used for emergency measures against excessive fluctuation of customer demand. A case study that optimizes the profit of an entire chain is used to demonstrate the algorithm. The outcomes of the study show that the proposed approach can yield feasible results (with near or even optimal solution) with much faster computational time as compared to the traditional simulation-based optimization.

KEYWORDS

Integrated Mathematical-Simulation Approach, Lateral Transshipment, Production-Distribution Planning, Safety Stock

1. INTRODUCTION

A supply chain's activities involve the production and distribution of finished goods to the hands of end-customers. They generally contain two parts: production system and distribution system. Production system involves in planning, managing, and operating for the whole manufacturing activities (e.g., manufacturing itself, part handling, sequencing, and inventory level controlling. Distribution system is the set of process that conducts since the stage of picking the right finished goods from supplier, manufacturer, or warehouse until delivering it to customer. Traditionally, production and distribution planning are planned independently. With an increase of information sharing within the company or between the company and logistics providers, integration of production-distribution planning becomes more critical for solution improvement. However, this integration comes with greater complexity,

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such as an increase in the size of the models and number of decision variables. An efficient method for solving these complex problems is needed that can provide a practical solution with reasonable computational time.

Disruption in the supply chain negatively affects a company's finance and reputation (Filbeck and Zhao, 2020). Shrivastava et al. (2019) explored financial and quality problems resulting from uncertainty in the supply chain. As an aim to optimize the profit of the supply chain operations, the network design of the chain including the flow of materials among members and their locations as well as their production and inventory plans need to be optimized. Conventionally, there are two common optimization approaches, namely mathematical or analytical and simulation-based approaches. Mathematical approach can give exact optimal results and can quickly solve problems but it provides static results and has a drawback to incorporate uncertainties. In addition, when the problems become bigger and more complex, it would be too complex to model by using the mathematical formulation. Rather, simulation-based optimization can be used to model and optimize more complex and realistic problems but it cannot guarantee an optimal solution and tends to take a long running time. As a result, this study proposes an integrated mathematical-simulation method, which is an effective way to both provide realistic results and reduce the computational time.

The problem with production or distribution planning is once they are planned, it is difficult to change. For example, once the actual orders are realized, it will be too late to change the production plan, which can result in shortages or excess inventories. One way to tackle this problem is an introduction of lateral transshipment. Lateral transshipment is defined as stock movements among members in an echelon (Peterson et al., 2012). This can increase the supply chain profit by balancing inventories among retailers and reducing possible shortages without changing the original production-distribution plan of the supply chain.

The objectives of this study are:

- Propose an integrated mathematical and simulation method for optimizing the production and distribution planning in a supply chain under uncertainty environments.
- Develop near or possibly optimal and feasible solution with relatively fast computational time, as compared to traditional simulation-based optimization methods.
- Introduce lateral transshipment among retailers to further increase the performance of the solution.

The rest of this paper is organized as follows. The literature review section summarizes the relevant literature as well as identifies possible research gaps in the field. The case study section defines the problem to be solved in this study. The methodology section explains the proposed integrated approach. Then, the overall outcomes are discussed. Lastly, the study is finalized in the conclusion section.

2. LITERATURE REVIEW

As literature in supply chain optimization increased in the last decade, only the literature related to the study regarding the production-distribution supply chain planning, lateral transshipment, as well as mathematical and simulation-based optimization are reviewed here.

2.1 Production-Distribution Supply Chain Planning

The modelling of production-distribution systems in supply chains has been discussed in many studies over the years. Many studies have proposed different methods in finding the optimal production-distribution planning under these complexities. Fahimnia et al. (2013) carried out a comprehensive review and critique on production-distribution planning and optimization literature. They also defined the production-distribution planning problem as the problem of simultaneously optimizing the decision variables from different functions that have traditionally been optimized sequentially. Senoussi et

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