Study on a new perishable food supply chain problem with shared returnable transport items

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Keywords: *Perishable food, Returnable transport items, Closed-loop supply chain.*

1 Introduction

In recent years, food supply chain (FSC) management is becoming one of the major economic and social concerns in the context of sustainable development, in particular due to the pressure of natural resources shortage, the increase of food waste and the compliance with the environmental policy of governments [1]. One solution to this is the replacement of one-way transport items with reusable and shareable ones (SRTIs), which can reduce the negative impact on the environment and protect foods better [2]. Although the use of SRTIs is a common practice in large food companies, finding the most efficient way to manage such a complex system remains a major challenge.

The introduction of SRTIs into a production-transportation system has given birth to reverse logistics owing to additional returned flow from the end-users, forming a closed-loop supply chain (CLSC). The traditional works focus on a general CLSC in which food-specific characteristics, such as perishability and short lifetime, are not considered, and the developed strategies and approaches cannot be applied to the closed-loop food supply chain (CLFSC) [3]. For this reason, this work investigates a new production-transportation planning problem for a CLFSC with SRTIs, in which the SRTIs can be used by different manufacturer partners to improve the overall supply chain performance.

2 Problem description

Consider a two-stage supply chain with a set of manufacturers belonging to a group company and a set of retailers. Manufacturers produce and deliver a single type of perishable food for retailers. The production capacity, vehicle fleet, inventory capacity, RTI investment budget and related costs are known. We assume perishable food has a limited shelf life, and its quality degrades one level per period resulting in a reduction in the selling price. RTIs are assumed to be managed by an information system and shared between manufacturers to save system costs.

A typical operation scenario is as follows: customers report their demand information to the group; meanwhile, each manufacturer reports its available supply resources, such as production capacity, fleets, and RTI inventories to the system. Upon receiving supply and demand information, the system of the group sends decisions to manufacturers. In accordance with system instructions, manufacturers produce, distribute products and recycle RTIs.

The studied problem determines production, transportation, inventory quantities, and loaded and empty RTI return quantities for each period of a considered time horizon. The objective is to maximize the total profit of the whole supply chain. The problem is formulated as a mixed-integer linear programming (MILP) model *P1*.

3 Solution method

Given that the problem is NP-hard, it is not efficient for optimization solvers like CPLEX to solve large-sized problems within a reasonable time. Therefore, a three-phase heuristic algorithm (TPHA) is developed to obtain near-optimal solutions. First, we transform model *P1* into a binary integer programming (BIP) model *P2* by relaxing integer variables. To solve model *P2*, we use the two-phase kernel search (KS) algorithm, which is known to be one of the most effective approaches for BIPs [4]. Based on the partial information (e.g., production quantity) by the KS, the third phase uses previous information to construct the delivery schedule, inventory schedules, etc., by several strategies. That is, a sub-optimal solution is derived through three phases.

4 Experiment results

The performance of the proposed TPHA is evaluated based on 225 randomly generated instances of various types with up to 10 manufacturers, 150 retailers and 15 periods. Numerical experimental results show that the performance of TPHA outperforms the direct use of a commercial solver CPLEX. Finally, we validate the effectiveness of the proposed shared RTIs strategy by a case study.

5 Conclusions

We investigate a new CLSC for perishable food products, considering shared RTIs, multiple manufacturers and retailers. To efficiently solve the problem, an efficient algorithm is devised to obtain near-optimal solutions within a short time. Numerical experiments validate the MILP model and demonstrate the effectiveness of the proposed TPHA. A case study analysis validates that the shared RTIs strategy can improve profitability compared to the non-shared one.

Reference

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