Bi-objective optimization of an integrated production inventory routing planning for perishable food

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1 Introduction

Perishable foods, including dairy, bakery, prepared food, and fresh meat, have a relatively short shelf life and start deteriorating once produced. Dealing with perishability within the food supply chain (FSC) is more challenging. The short shelf life imposes new constraints on the production lot size and the inventory quantity, while requiring special storage and transportation conditions. High cost may be incurred by high food waste and more frequent delivery. Thus the stakeholders and practitioners are pursuing an integrated and well-designed plan to reduce the total FSC cost. On the other hand, consumers are becoming more critical when buying perishable food. They need fresher food with lower price. If the price stays unchanged while the food quality decreases, the consumption satisfaction may decrease.

In most FSCs, the customers' preference in buying fresher food is often left behind, i.e. the decision makers aim at minimizing the total FSC cost, without considering the customers' requirements on food quality; however, in perishable food supply chain, the quality of food received by customers is directly related to the service level. Keep pursuing lower cost may frustrate the customers. This is not realistic in highly competitive globalized market where the manufacturers are striving to serve their customers with fresher food. So the planner should simultaneously control the cost and service level.

The cost and freshness trade-off has already been investigated within the production distribution planning problem [1] and the vehicle routing problem with time windows [2]. An integrated production inventory routing problem (PIRP) with explicitly tracing the food quality is presented by [3]. The PIRP is an integrated planning that simultaneously optimize the production, inventory and routing decisions [4]. They use a price markdown strategy to avoid lost sale caused by perishability; however, in reality, consumers may be forced to buy food which is not in the best condition with the same price. To detect the cost and service level (quality) trade-off, we formulate the PIRP for perishable food with a bi-objective framework. The two objectives are to minimize the total cost and to maximize the average quality of food consumed by the customers.

2 Solution method

We propose a bi-objective mixed integer linear programming model for the proposed problem. To solve the proposed problem, we use ϵ-constraint method which is known to be one of the most effective approaches for solving multi-objective optimization problems, especially for a bi-objective optimization problem [5]. Its basic idea is to construct and solve a series of single objective problems with transforming the other objectives into constraints. With the known NP-hardness of the proposed problem, we do not expect to solve the medium- and large-size instances directly with LP solver, e.g. CPLEX. Instead, a fast heuristic method that can quickly provide good quality solutions is desired. We develop an ϵ-constraint based heuristic (H) to get approximate pareto front. By applying the ϵ-constraint framework, the original bi-objective problem is transformed into a sequence of single objective problems. Then the two-phase iterative heuristic (denoted by IM-VRP) proposed by [6] is adapted to solve the single objective problems. The basic idea of IM-VRP is to decompose the proposed model into two sub-problems, which are solved sequentially. The first phase model determines the production, inventory and replenishing decisions, while the second phase model determines the routing decisions with a fleet of capacitated vehicles. Particularly, the two phases are connected with an approximate routing cost parameter that is updated after each iteration. We refer the readers to [6] for the full description of IM-VRP.

3 Computational results

We compile the algorithms in C++ using Microsoft Visual Studio 2010 linked with Cplex version 12.6.0. All test runs are performed on a CORE CPU 2.5 GHz with 8GB RAM. We generate 12 different scenarios with 5 instances for each based on that of [7], where an inventory routing problem was solved. We first test small-size examples and then test the 60 generated instances. The results show the effectiveness and efficiency of the proposed algorithm.

4 Conclusion and perspective

We propose a new problem dealing with perishable food based on a bi-objective framework. We develop an ϵ-constraint based heuristic to solve the proposed problem and 60 randomly generated instances are tested.

For the future work, we may conduct more experiments to analyze the impact of the parameter settings and the cost structure. More efficient multi-objective algorithms could be developed to solve the proposed problem in larger size with less computational time.

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