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A vehicle routing problem of both refrigerated- and general-type vehicles for perishable food products delivery

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ABSTRACT

This study examines a vehicle routing problem that encompasses both refrigerated- and general-type of vehicles for multi-commodity perishable food products delivery. It is assumed that both the location and the volume of the ordered food products for each customer are known. Furthermore, the capacity, maximum delivery time, and available number of both refrigerated- and general-type of vehicles are predetermined. By reflecting these characteristics, we develop a nonlinear mathematical model and a heuristic algorithm to generate efficient vehicle routings with the objective of maximizing the total level of the customer satisfaction which is dependent on the freshness of delivered food products. In addition, numerical examples and sensitivity analysis are provided to show the validity of the model. The aim of this study is to confirm the performance and the availability of refrigerated-type vehicle for perishable food products delivery compared with general-type one.

1. Introduction

The development of Information and Communication Technologies (ICT) has dramatically changed people's daily lives in our modern society. Among those changes, people's shopping style is one of the areas most significantly affected by those kinds of trends. Before the development of ICT, people would visit local stores to purchase products which they needed in their daily lives. In addition, they tended to visit large warehouse stores usually located far from their home to purchase their daily necessities on weekend. People spent a great deal of time for driving toward shopping stores, choosing various products and carrying out items to their home. However, due to the development of ICT, people started to purchase their daily necessities not only at local shopping stores, but also on-line shopping stores through internet or phone. As a result, market size and market share of on-line shopping has continuously increased. As we can see in Fig. 1, the market volume of online shopping has increased exponentially in Korea.

In addition, the perishable food products such as vegetables, fishes and dairy goods can be purchased through on-line shopping stores. Customers can get their items within several hours during the working day.

The popularization of on-line shopping has allowed people to enjoy the convenience of shopping at their home with little effort. However, at the same time, it causes some troubles for managing the delivery of food products because of the customer satisfaction issues coming from the freshness of delivered food products. In general, food products are characterized as perishable items. Their freshness is significantly affected by the time duration and temperature environment during the delivery. Thus, when the food products are delivered to lots of customers, it is hard to keep the freshness of delivered food products due to extended travel time and frequent stops to serve customers (Hsu et al., 2007). Therefore, the efficiency of the vehicle routing scheduling is regarded as an important issue to maintain the freshness of customer's food products. To ensure the freshness of the food products, many online shopping stores that sell perishable food products operate refrigerated-type vehicles that can control their internal temperature using cooling equipment. In this case, customers can get more fresh food products and company can achieve higher level of the customer satisfaction. However, refrigerated-type vehicles are more expensive and require more fuel than general-type vehicles; therefore, it is not easy to operate refrigerated-type vehicles for every delivery because of the economic issue. As a result, they tend

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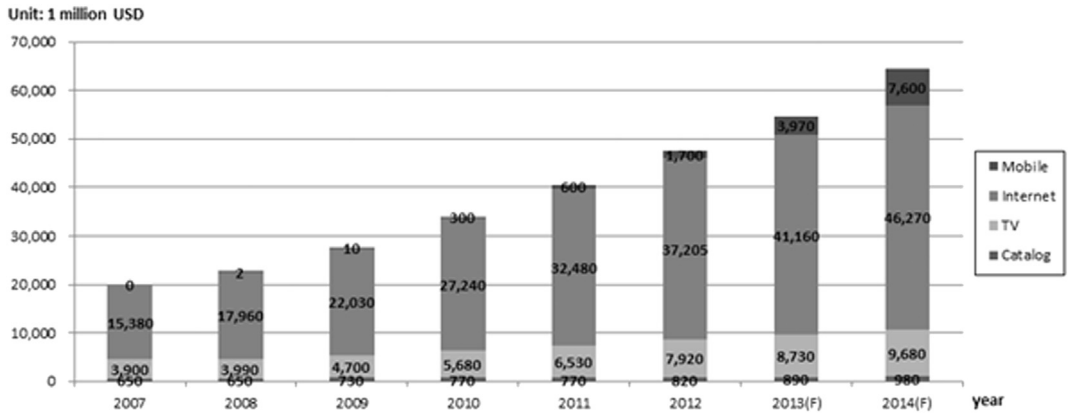

Fig. 1. Increasing the market size of online shopping in Korea.

to operate both refrigerated- and general-type vehicles to cover customer orders.

In this research, we consider a vehicle routing problem with both refrigerated- and general-type vehicles for multi-commodity perishable food products delivery to maximize the total sum of the customer satisfaction, which is dependent on the freshness of the delivered food products. When vehicles start their travel from the depot, the freshness of each food product type is assumed to be perfect. During the delivery, the freshness of each food product is regarded to reduce based on the elapsed traveling time with the freshness reduction rate of each food product type. However, when the food products are delivered via refrigerated-type vehicle, freshness of delivered food is higher due to its freshness-control function. But when the storage door of both general- and refrigerated-type vehicle is opened for picking out some food products during delivery, all food products which remaining at storage are regarded to lose certain amount of freshness. In addition, we assumed that the locations, quantity and food product type of demand (=customer orders) and required service for each customer are known and the capacity of each refrigerated- and general-type vehicle can be designed differently. With these conditions, we try to derive an efficient delivery schedule for all vehicles through mathematical modeling and efficient solving algorithm. Based on the result of various numerical experiments, we want to provide a guideline for delivery schedule of multi-commodity perishable food product via refrigerated- and general-type vehicle. Because the purchasing and operating cost of both refrigerated- and general-type vehicles are significantly different according to the specification of them, we do not investigate cost related elements in this study.

2. Literature review

In this section, we introduce previous vehicle routing problems for perishable food products. If someone wants to investigate an overall vehicle routing problem, please refer to Eksioglu et al. (2009) for the classification of the vehicle routing problem.

Various researches have been conducted to find an efficient vehicle routing policy and supply chain design for perishable goods. Tarantilis and Kiranoudis (2001) solved a heterogeneous fixed-fleet vehicle routing problem to find a vehicle operation schedule for fresh milk. A threshold-acceptance-based algorithm was developed that aimed to satisfy the needs of a company that planned to generate a schedule repeatedly, many times over a day. Tarantilis and Kiranoudis (2002) also addressed an open multi-depot vehicle routing problem for distributing fresh meat from depots to their customers located in an area of the city of Athens. A stochastic search meta-heuristic algorithm was proposed to solve the problem. Prindezis et al. (2003) suggested an application service provider that would offer the services of distribution logistics for central food markets that sell and distribute fresh food products. A vehicle routing problem was proposed and solved via appropriate meta-heuristic techniques. Campbell and Savelsbergh (2005) suggested a decision support tool for consumer direct grocery initiatives. In their article, the authors defined routing and scheduling problems for grocery delivery service and proposed an insertion heuristic to derive vehicle schedules. In the problem, the company decides which deliveries to accept or reject as well as vehicle schedules for the accepted deliveries so as to maximize expected profits. With an unpredictable demand, the authors define routing and scheduling problems and solving algorithm. Osvald and Stirn (2008) presented an algorithm for the distribution of fresh vegetables in which the perishability represents a critical factor. They dealt the problem with time windows and time-dependent travel-times (VRPTWTD) where the travel-times between two nodes are related both the distance and on the time of the day. Schmid et al. (2009) developed hybrid solution approach for ready-mixed concrete delivery. Concrete product is a perishable good, in the sense that it hardens after a certain amount of time. Due to this characteristic, the authors developed an integer mathematical model to deliver concrete products from plants to construction sites using a heterogeneous fleet of vehicles. Optimization and heuristic techniques are integrated to derive vehicle schedules. Recently, Hasani et al. (2012) designed a closed-loop supply chain for perishable goods. In this paper, multiple periods, multiple products and multiple supply chain echelons were considered with uncertain demand. Commercial optimization software LINGO version 8 (LINGO systems Inc.) was applied to derive a solution to the proposed mathematical model. Amorim et al. (2013) considered the issue of lot sizing versus batching in the production and distribution planning of perishable goods. The authors proved the importance of lot sizing for make-to-order systems when perishability is explicitly considered. Govindan et al. (2014) suggested a two-echelon multiple-vehicle location-routing problem for supply chain network of perishable food. A multi-objective optimization model for perishable food supply chain network was developed. The goal was to determine the number and location of facilities and to optimize the amount of products delivered to lower stages and routes at each level. In above researches, heterogeneous types of vehicles are considered to deliver perishable products. However, no refrigerated type of vehicle was considered to deliver perishable products for freshness management.