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Evaluation of cost structure and impact of parameters in location-routing problem with time windows

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Abstract

This study presents the evaluation and application of the location-routing problem with time windows (LRPTW) in the distribution network. The ordinary location-routing problem is considered one of the integrated logistics system tools extended from the original facility location problem. By adding the time windows into the problem, it provides the room to improve the service quality and customer satisfaction. To understand the impact of the main parameters, nine scenarios of the Osaka distribution network from freight carrier were tested with different depot location, depot size, and vehicle size. It was observed that the large size depot, located in Minato-ku, serving by large size vehicle results in the lowest overall cost. The characteristics of depot, vehicle, and transport information were also discussed in detail.

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Keywords: location-routing; time windows; branch-and-price; column generation

1. Introduction

In the distribution management, determining the suitable sites of the business center is considered one of the most essential strategies in supply chain. This decision is prepared for setting up a factory, warehouse, retail store, or in other public services, i.e. hospital, police station, fire station, etc. Thus the facility location is required at several points throughout the business development. Traditionally, after the facility or warehouse was set up, the transportation

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process has been determined and operated as a short-term basis. This method refers to the conventional location first, routing second approach (Bruns & Klose, 1996). While the other decisions can be examined more frequently at the short-term operational stage, the facility must be located earlier in the long term strategic planning. However, it was proved that the combination of these problems to become a Location-Routing Problem (LRP) reduces the cost over the long-term horizon. Solving them together early in the planning horizon provides significant cost savings, improves productivity, and returns positive impacts for both operators and society (Rand, 1976; Madsen, 1983; Salhi & Rand, 1989).

Moreover, in the context of logistics management, much attention has been paid in improving the service quality by increasing customer satisfaction. It was recommended by Min et al. (1998) that the future LRP studies should be extended to consider the presence of time windows since the customers often request the service time and deadlines. Some might argue that the delivery time is relatively small compared with the time horizon of the facility location process. However, the technology improvement enables the growth of a new market, which is responsive to customers' behavior and their needs, especially the importance of "just in time" policies (Gonzalez-Feliu, et al., 2012). That is why, the time windows are now almost essential in different businesses such as bank deliveries, postal deliveries, industrial refuse collection, school bus routing and scheduling, or the modern e-commerce (Solomon & Desrosiers, 1988).

According to the latest comprehensive surveys (Nagy & Salhi, 2007; Drexl & Schneider, 2013; Prodhon & Prins, 2014), the LRP-related researches are growing in number. However, few of literature on location problem have been applied to specific applications or case studies. The application-based publications are amount only less than one fifth (Nagy & Salhi, 2007). Current et al (2002) summarized the reasons behind this phenomenon. First, the application of location problem practices the existing model and solution technique. It does not provide a scientific approach for research literature. Second, the real world business and industries handle this task by consultants or professional firms. They are not interested or motivated in sharing such experiences. Third, the private sectors treat their valuable knowledge in this area secretly. Nonetheless, it is still important to advance the modelling together with the specific application in real world problem.

By considering the issues mentioned above, while the early LRP studies provide the framework and algorithm development with hypothesis testing instances, the evaluation and investigation of specific applications is still being questioned. In LRP model, two cost components, i.e. location and routing, influence the calculation process and tradeoffs must be made between them. The ratio between these two components varies among different business. For example, the cost ratio of pharmaceuticals business is 0.26, the paper business is 0.85, and the consumer merchandising business is 1.56 (Srivastava, 1986). To assess the LRP under different environment and apply to the real world problem is not only provide a broader understanding of location-routing options, but also convincing evidences of its efficiency and practicality. This problem was motivated by the observation of LRPTW by Ponboon et al (2014) that in some contexts, the cost saving might not be influenced by only depot location, route length, and time windows. It may be more economical to change the configuration of the underlying parameter instead of open new facilities. Therefore, a full understanding of that observation is examined in this study. In other words, the main purpose of this study helps us to make decisions on;

- How many and which depots to be operated?
- Which customers to be assigned to which depots?
- What are the sequences of the customers?
- What are the truck routes?
- How is the difference between opening the new depot and enlarging the old depot?
- What is the effect on the size of vehicle?

The impact of external characteristics is assessed and evaluated by various factors. The factors that influence the distribution system include depot location, depot and vehicle capacities, their fixed costs, and time windows. To handle the location, routing, and time windows together, the scheme of the location-routing problem with time windows (LRPTW) with exact algorithm is used as a main tool. By using the branch-and-price algorithm developed by Ponboon et al. (2014), this study explores the effect of various cost component factors in logistics systems. The Osaka road network is selected as a based case of distribution network.