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Application of a combined fuzzy multiple criteria decision making and optimization programming model to the container transportation demand split

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ABSTRACT

The container transportation demand split is one of the most important decision issues for government transportation departments and port organizations. In previous studies, many researchers assumed that the shipping carrier would aim to minimize the total operation cost by selecting an appropriate port as the most favorable one to call, and the shipper would aim to minimize the inland freight cost by selecting the nearest port as the most favorable one to import and export international trade containers. Thus, a number of mathematical programming models have been developed. But in practice, the shipping carrier not only aims to minimize the total operation cost but also takes into account other criteria such as the volume of containers and port facility conditions when choosing an appropriate port as the most favorable one to call. The shipper not only aims to minimize the inland freight cost but also takes into account the frequency of ship callings when choosing an appropriate port as the most favorable one to import and export international trade containers.

Thus, the purpose of this paper is to formulate a combined fuzzy multiple criteria decision making and optimization programming model for solving the container transportation demand split problem. There are two stages in this combined model: in stage one, we first compute the container transportation demand split rate by using fuzzy multiple criteria decision making (MCDM) method; whereas in stage two, an optimization mathematical programming network model is proposed for determining the inland origin destination (O-D) of import/export containers. The utilization of the proposed model is demonstrated with a case of Taiwanese ports. The results show that the proposed combined fuzzy MCDM and optimization programming model can be used to explain the container transportation demand split practice.

1. Introduction

In Taiwan, almost 37.37% (2,210,265 TEUs) of the total volume of imported and exported international trade containers is to/from northern Taiwan, with 23.47% (1,388,000 TEUs) to/from central Taiwan, and 39.16% (2,316,000 TEUs) to/from southern Taiwan, respectively. On the other hand, there are three major international container ports in Taiwan. They are the Port of Keelung in northern Taiwan, the Port of Taichung in central Taiwan and the Port of Kaohsiung in southern Taiwan, respectively. The container throughput splits for the Port of Keelung, the Port of Taichung and the Port of Kaohsiung are 28.64% (1,693,589 TEUs), 13.52% (799,817 TEUs) and 57.84% (3,420,859 TEUs), respectively. That is, many of the international trade containers to/from northern Taiwan and central Taiwan were imported/exported via the Port of Kaohsiung in southern Taiwan.

In previous studies, many researchers assumed that the shipping carrier would aim to minimize the total operation cost by selecting an appropriate port as the most favorable one to call. Thus, a number of mathematical programming models have been developed. But in practice, the shipping carrier not only aims to minimize the total operation cost but also takes into account other criteria such as the volume of containers, port facility, port location, port operation efficiency and other conditions. The port choice behavior of the carrier is a multiple criteria decision making (MCDM) problem. The MCDM is an appropriate method for solving the port choice problem of the carrier.

On the other hand, since 1990s Taiwanese government actively pushed the Port of Kaohsiung to become the transshipment center for the Far Eastern region by improving computer hardware and software, the inland transportation system, the Customs clearance operation and reducing the container handling charges. Therefore the Port of Kaohsiung attracted a lot of liners to call. As a result, the

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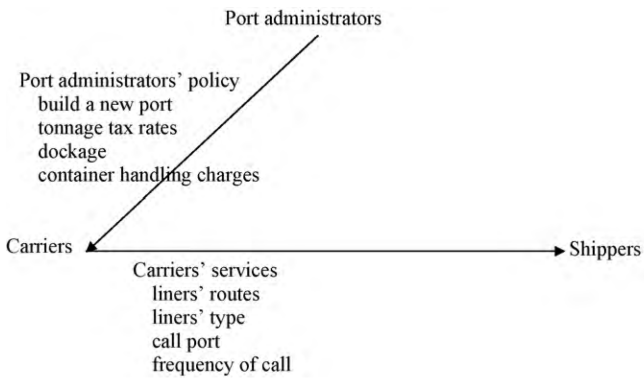

Fig. 1. Relationship between port administrators, carriers and shippers.

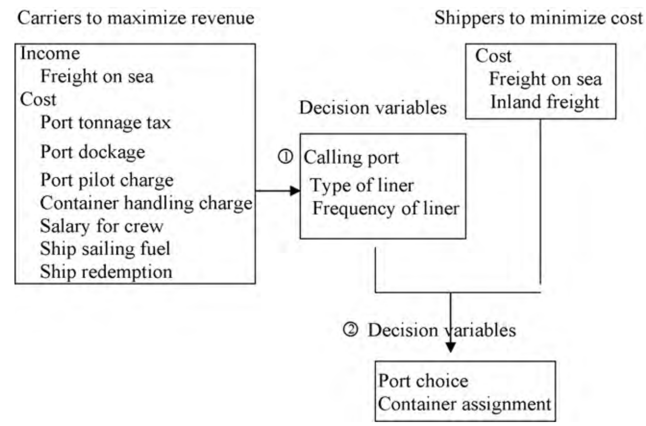

Fig. 2. Structure of Stackerlberg model for port choice.

frequency of callings of the Port of Kaohsiung is larger than that of the Port of Keelung and the Port of Taichung. In previous studies researchers assumed that the shippers would aim to minimize the inland freight costs by selecting the nearest port as the most favorable one to import and export international trade containers. These researchers developed some container transportation demand split models by using mathematical programming. In other words, in those models the shippers in northern Taiwan would choose the Port of Keelung for importing/exporting international trade containers, the shippers in central Taiwan would choose the Port of Taichung for importing/exporting international trade containers, and the shippers in southern Taiwan would choose the Port of Kaohsiung for importing/exporting international trade containers. But in fact, many of the shippers in the northern Taiwan area decided to export and import their containers via the Port of Kaohsiung in southern Taiwan because they attached a great deal of importance to the frequency of liner calls when making port choice decision even though it meant added time and additional freight costs. That is why many of the international trade containers to/from northern Taiwan are imported/exported via the Port of Kaohsiung in southern Taiwan. Those models proposed in previous studies neglect that shippers not only aim to minimize the inland freight costs but also take into account the frequency of ship callings when making port choice decision in the real world. Those model proposed in previous studies cannot be used to fully explain the actual port choice behaviors of shippers in Taiwan area.

Thus, the purpose of this paper is to formulate a combined fuzzy MCDM and optimization programming model for solving the container transportation demand split problem in Taiwan. There are two stages in this combined model: in stage one, we first compute the container transportation demand split rate by using fuzzy MCDM method; whereas in stage two, an optimization mathematical programming network model is proposed for determining the inland origin destination (O-D) of import/export containers.

2. Literature review

2.1. Port choice

Yang [1] discussed that the international trade container transportation market could be regarded as a Stackerlberg market. That is, three players including port administrators, carriers and domestic shippers, can be considered in the international container transportation market. Port administrators can be regarded as the superior players, because they have complete information about the optimal behaviors of both carriers and domestic shippers under a given port management policy. Carriers, on the contrary, can be regarded as superiors and leaders to domestic shippers who are followers in the market, because carriers have complete information about the optimal behaviors of shippers under given carriers' services. This leads to a bi-level Stackerlberg problem. The relationship between port administrators, carriers, and shippers is shown in Fig. 1.

In the Stackerlberg model for port choice, the carrier aims to maximize his net revenue by using his strategies of routing, vessel type, call port and frequency of call on each route. While making these strategies, the carriers should take into account all information concerning the behaviors of shippers. For example, carriers first investigate the origin destination of foreign trade containers, then make an estimation of flows of containers, and finally decide the services and declare it. So carriers have complete information about domestic shippers. For this reason carriers can be regarded as leaders and domestic shippers can be regarded as followers in the foreign trade container transportation market.

Domestic shippers may choose their port to minimize the total inland transportation cost under a given liner service. They also consider the port access time. However, the port access time is often neglected when modeling. According to the above analysis, the structure of Stackerlberg model for port choice can be constructed in Fig. 2. In Fig. 2, we note that there are two stages in the model. In stage one, the shipping carrier aims to maximize the revenue and choose an appropriate port to call. In stage two, the shipper aims to minimize the inland transportation cost and choose an appropriate port to import/export international trade containers.

2.2. Fuzzy MCDM

The location selection is one of the most important decision issues for business organizations. Many precision-based methods for location selection have been developed [2–5]. The MCDM methods were provided to deal with the problem of ranking and selecting locations under multiple criteria [6,7].

In general, the selection of a best location for business organizations from two or more alternatives locations on the basis of two or more factors is a MCDM problem. Under many situations, the values for the qualitative criteria are often imprecisely defined for the decision maker. It is not easy to precisely quantify the ratings of each alternative location, and the precision-based methods as stated above are not adequate to deal with the location selection problem [8–10]. Since human judgments including preference are often vague and can not estimate his preference with an exact numerical value. It is more realistic to use linguistic terms to describe the desired value and important weight of criteria, e.g. "very low", "low", "fair", "high", "very high", etc. [11,12]. Due to this type of existing fuzziness in the location selection process, fuzzy set theory is an appropriate method for dealing with uncertainty, and the