Modelling Mode Choice in Freight Transportation Based on Deterministic Logistics Cost Model

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Abstract—Freight transportation is very important sector for national economies. The well-planned freight transportation system makes a positive contributions to life of people. An important part of any numerical analysis of freight transportation is a ability for forecasting the demand. Freight transportation demand is far more complex than passenger transportation demand. It is clear that firm is the basic decision-making unit in the transportation of freight. This paper summarizes the results of deterministic logistics cost analysis based on stated preference technique. Deterministic logistics cost model is developed at the level of the individual firm. The dataset used for this study is the result of 14 interviews with ceramic merchants, which have been realised in Antalya region, Turkey. In conclusion, which factors are important for create deterministic logistics costs model and calculate logistics costs based on this model were determined in this study.

Index Terms—freight transportation, logistics costs, deterministic model, demand analysis, stated preference.

I. INTRODUCTION

Interest in modeling and analysis work in freight transportation has increased greatly over the past few years for variety reasons. The well-planned freight transportation system makes a positive contributions to life of people. An important component of any analysis of freight transportation is a capability for forecasting the demand for a certain type of service under given set of conditions. Logistics is one of the most important activities in freight transportation. Logistics represents a collection of activities that ensures the availability of the right products in the right quantity to the right customer at the right time [1]. Logistics activities serve as a link between production and consumption and essentially provide a bridge between production and market locations or suppliers separated by distance and time [2]. Different values are added to a product at various stages of its life cycle. Production and manufacturing adds form value by converting the raw material or components into finished parts. Place value is provided through transportation by moving the product where it is needed. Time value is provided through storage and inventory control ensuring the availability of the product when needed. Possesion value is added to the product through marketing and sales [1]. The primary objective of logistics is to provide appropriate standard customer service at the minimum possible total logistics cost. Customer service is measured by the availability of the required product of acceptable quality within the specified time [3]. This paper summarizes the results of deterministic logistics cost analysis based on stated preference technique. Deterministic logistics cost model is developed at the level of the individual firm. The dataset used for this study is the result of 50 interviews with cement merchants, which were realised in Antalya region, Turkey. In conclusion, which factors are important for create deterministic logistics costs model and calculate logistics costs based on this model were determined in this study.

II. FREIGHT TRANSPORTATION DEMAND

Freight transportation makes a vital contribution to the economy and society. Freight transportation helps production, industry, trade and consumption activities by ensuring the efficient movement and timely availability of raw materials and finished goods. Advances in freight transportation have been a major origin of productivity growth in the economies of many countries. Forecasting the developments of future transportation is essential for freight transportation policy planning. Modelling freight transportation demand is far more complex than passenger transportation demand. Modelling studies related the freight transportation has been carried out since 1960. The first models about freight demand were aggregate models dealing with freight transportation. More recent models, are dissagregate models. Classical four step freight demand modeling technique is recognizes that freight demand is derived from economic activity. It involves comprehensive interrelationships among economic activity, production and consumption nodes, distribution or linkages between production and consumption nodes, mode choice and shipment size decisions, vehicle trips, and route assignments [4]. Figure 1 illustrates the model components and their key inputs of classical freight modeling approach [5].
There is a three type of decisions which are represented as a complex hierarchy of choices in freight transportation demand analysis studies. These are long run, intermediate and short run decisions. A firm ultimately makes a decisions on the purchase of its transportation services. The long run decisions that a manager of firm has to make a concerns the location of the plant.

Intermediate decisions dealing with the production involving the choice of technology of production and level of output [6]. The short run decisions involves the choice of mode, shipment size and point of supply given the annual use rate of inputs. In terms of production theory, this is somewhat restrictive, since it allows no factor substitution between the demand for transportation and other factors, but it does allow for substitution within the transportation and logistics cost elements [7]. Therefore, a demand model using the logistics choice process as its basis must be categorized as a short run freight demand model. In a short run demand model, the annual demand for input material is used as only transportation related choices, such as origin of supplier, mode of transport. This study then proceeds to develop the short-run model of freight demand based on logistics cost elements. The model examined in this paper is disaggregate, explanatory and considers the firm as the basic decision making unit.

III. LOGISTICS COST MODEL PARAMETERS

Over the last four decades a substantial researches about to mode choice on the basis of logistics cost model for the freight demand analysis was reported in the literature. These costs typically involved in the decision process are: purchase costs, ordering costs, transportation costs, in transit-carrying costs, inventory costs, inventory carrying costs, lost and damage costs, safety (stock-out) costs. Table I illustrates the mainly cost components used at these models. In the cells of table, “Y” means “YES” and “N” means No” Names of authors and their publications which are include these models are listed below. Because of the planning and operational decisions of one cost type typically has an impact on the other cost type, logistics decisions are usually based on total cost approach.

1. “Intermodal transportation and inventory cost model highway-to-rail intermodal user’s manual” [8].
5. Y. Sheffi, “Carrier/shipper interactions in the transportation market: An analytical framework” [12].
8. A. Kanafani, “Methodology for mode selection in corridor analysis of freight transportation” [6].

For example, inventory and transportation decisions are very closely related. If a slower mode is used for transportation because it is cheaper, than a higher level of inventory may be needed. On the other hand, if a faster mode is used, than a lower inventory level may be maintained. Therefore a trade-off is need to determine the optimal inventory level. The primary objectives of logistics is to provide customer service at the minimum total cost. Total cost includes the costs incurred to perform all the logistic functions in order to provide world-class customer service [3].

The total cost approach has been a core principle in transportation and logistics decision making activity in the mid 1950s [15]. In developing the methodology for mode selection based on logistics cost model, we shall adopt the perspective of the receiver. The receiver is a rational economic decision maker who tries to minimize total logistics costs for the delivered product. A short explanation of logistics costs parameters are presented below.

A. Ordering Costs

If the ordering cost is represented by “OC”, the ordering costs per shipment is represented by “a”, then calculation of ordering cost as follows:

\[ OC = a \]  

(1)

B. Transportation Costs

If the transportation cost per shipment is represented by “TC”, transportation costs per unit product is represented by “c”, the amount of product carried per shipment is represented by “u”, then calculation of transportation cost is as follows:

\[ TC = u \cdot c \]  

(2)
C. In-Transit Carrying Costs

If the in-transit carrying cost per shipment is represented by “ITC”, the amount of product carried per shipment is represented by “u”, value per unit product is represented by “p”, annual interest rate is represented by “f”, and transportation costs per unit product is represented by “k”, then the calculation of in-transit carrying costs is as follows:

\[ ITC = u \cdot p \cdot \frac{f}{365} \cdot t \] (3)

D. Inventory Costs

Average inventory level was recognized 50% in this study. If inventory cost is represented by “IC”, the annual storage cost is represented by “M”, annual demand is represented by “T”, the amount of product carried per shipment is represented by “u”, value per unit product is represented by “p”, annual interest rate is represented by “f”, then the calculation of “IC” is rearranged as follows:

\[ IC = \left( \frac{M}{T} \cdot \frac{u}{2} \right) + \left( \frac{P \cdot f \cdot 365 \cdot u}{T \cdot k \cdot 2} \right) \] (4)

E. Safety Stock Costs

If the safety stock cost is represented by “SC”, the safety stock level is represented by “n”, then the calculation of safety stock costs as follows:

\[ SC = \left( \frac{M \cdot n}{T} \right) + \left( \frac{P \cdot f \cdot 365 \cdot n}{T \cdot k} \right) = \left( \frac{d \cdot n}{k} \right) + \left( \frac{P \cdot f \cdot n}{k} \right) \] (5)

F. Loss and Damage Costs

Loss and damage cost includes the actual value of the material lost and damaged for which the shipper is not compensated by the carrier [16]. If the loss and damage cost is represented by “LDC”, the amount of lost and damaged product is represented by “z”, then the calculation of safety stock costs as follows:

\[ LDC = z \cdot P \] (6)

With a view to examine the process involved in selecting an appropriate freight demand analysis strategy, it is useful to represent the decision variables defining alternative short run analysis strategies as the choice of origin represented by i, shipment size represented by q and mode of transportation represented by m. The criteria for an alternative i,m,q to be an optimal logistics strategy is satisfaction of the following condition [10]:

\[ w_{i,m,q} \leq w_{i,m,q}' \quad \forall i,m,q \in A \] (9)

A model developed upon this assumption will be referred to as a deterministic cost model of short-run freight demand. The model states:

\[ P_i  = \begin{cases} 1, & \text{if } w_{i,m,q} \leq w_{i,m,q}' \quad \forall i,m,q \in A \ 
0, & \text{otherwise} \end{cases} \]

where w_{i,m,q} and w_{i,m,q}' are fully observed. The second approach assumes that the logistics cost function is not fully observable. According to this approach, logistics cost function consists of two parts. The first part is f observable and the second part is unobservable. In this study, mode choice was modelled based on deterministic logistics cost model in freight transportation. The deterministic logistics cost model assumes that the total logistics cost function is fully observable. The objective function for the firm’s logistics strategy is to minimize the total logistics costs.

IV. Empirical Study

Antalya is the biggest tourism center of Turkey, located south of Turkey. Therefore, the population of city is increasing continuously and construction activities are too much accordingly. Ceramic is the basic elements of the building construction sector. Some of ceramics used in the construction sector in Antalya province are transported from Canakkale Ceramic Factory which is located at Çan (the town of Çanakkale province). There are two transportation modes used for carrying of ceramics from Çan to Antalya. One of them is the road transportation. Other is the intermodal transportation. Burdur is transfer station for intermodal transportation. Fig. 2 and Fig. 3 illustrate the transportation corridor analysed in this study.

![Figure 2. Direct road transportation](image-url)
Since this transportation corridor has a big potential about both transportation types and demand characteristics knowledge, the surveys were conducted to transportation managers of 14 ceramics firms whose shipments were carried by using this transportation corridor. After surveys were conducted, data set entered into an Excel spreadsheet. Fig. 4 illustrates the Excel spreadsheet included dataset table.

Total logistics costs for each transportation operations made within one year of each company were calculated by using total logistics cost model (Eq. 8). Total logistics costs were calculated separately for the intermodal and direct road transportation. Fig. 5 illustrates graphically the components of total logistics costs.

As can be seen in Fig. 5, it is assumed that total logistics costs consists of three main parts in the study:
- Ordering costs
- Transportation related costs which is include transportation costs, in-transit carrying costs and loss-damage costs
- Inventory related costs which is include inventory costs and safety stock costs.

One can see Fig. 5 that, percentage of transportation related costs over the other cost components is dominant. Nevertheless, inventory related costs is the typically other important logistics cost parameter. This figure shows that, variables related transportation related costs are an important factors creating logistics cost model. Cost components of inventory related costs and transportation related costs are shown in Fig. 6 and Fig. 7 respectively.

Components of transportation related costs reported in Fig. 7 indicate that the transportation costs are largely composed of direct road transportation costs. It is followed by intermodal transportation costs. The other two cost parameters are less effective on transportation related costs. This implies that the parameters that the influence the calculation of transportation costs are very important factors creating transportation related costs. Transportation costs consists of two parameters: transportation costs per unit and the amount of product carried per shipment. The second parameter is used almost all cost calculations in total logistics cost model. Therefore, it is assumed that, this parameter not a determining factor on the cost calculation. As a result, transportation costs parameter is determined as the most important factor defining short run freight demand.
analysis strategy based on deterministic logistics cost model.

V. CONCLUSION

Freight transportation is very important activity for national economies. An important part of any quantitative analysis of freight transportation is a ability for forecasting the demand for a certain type of condition under a given set of possibility. This paper summarized the study on selecting an appropriate freight demand analysis strategy based on deterministic logistics cost model. The data set used for this study is the result of 14 interviews about cement sector firms, which have been realized in the Turkish region of Antalya. The results confirm that, the logistics cost model is most affected by transportation cost parameter. Depending on this situation it can be said that, if the costs of transportation modes are rearranged, the possibility of firms rely on intermodal transportation rather than road transportation will increase. This result is very important authorized persons dealing with the mode choice activities in freight transportation.

REFERENCES


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