ANALYSIS OF BOTTLENECKS IMPEDING STABLE SUPPLY OF INTERNATIONAL INLAND FREIGHT TRANSPORT*

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1. Introduction

Landlocked countries have no seaport by their nature. For this reason, maritime transport, which, characteristically, has a low unit transport cost, cannot be used within their territories. Thus, land transport (truck, rail, etc.) must be used through transit countries for accessing seaport. In accessing to seaport, shippers in landlocked countries must pass across at least 1 border. In case of developing countries, border is normally to be a bottleneck of stable supply of inland freight transport in terms of Shipping Time (SC) due to insufficient infrastructure (e.g. scanner for goods inspection is insufficient[1)]). Seaport in developing country is also recognized as bottlenecks due to long waiting time and its variability. These phenomena can be observed in developed country as well, nevertheless, its scale and impact in developing countries must be higher. In summary, delay at the border and seaport are the most significant problem of inland freight transport, particularly in developing countries.

Due to the Variability of Shipping Time (VST), it can be assumed that shippers make a decision for route choice by their past shipping experiences since information on variability is not provided at all, prior to the departure. Particularly shipping between same OD repeatedly, experiences of past shipping might be reflected for quotation for next Shipping Time (ST). Supposed that past shipping was suffered from long delay at the border, next shipping will be somewhat conservative comparing to previous one. In this context, it is needed to incorporate (i) experiences of past shippings and (ii) VST. Regarding seaport choice, it will not be changed in short term since inland freight transport needs several cost and processing (e.g. relocation of office and warehouses), thus, this model foresee how shippers change their route/seaport choice in the mid-term period.

In order to express past shipping experiences for quotation of next SC, Hölder Mean Approach is applied in this study. There are several studies on quotation for next travel time, for example, Iida *et al.*[2-5)] developed model under the uncertainty and additional information by repeated route choice experiences. Horowitz[6)] discusses stability of convergence by applying trip experiences to link cost function of route assignment model. However, these approaches are all based upon linear function which compares the impact of the past trips. In this study, quotation of ST of the next trip is inferred by applying Hölder Mean (HM) Approach which is enabling to incorporate impact of occurrence of uncertain phenomena (in this study, delay) in the past and express evaluation mechanism for past trips. Modeling process for quotation for ST of next trip based on Hölder Mean approach is basically based on Morichi *et al*[8)]. Purpose and objective of this study can be listed up as followings;

- To develop model of quotation for next shipping time considering experiences of past shippings
- To analyze which trip (experience) affects quotation for next shipping time
- To develop model of generalized cost incorporating shipping time variability
- To observe change of shippers' route choice in mid-term period

2. Quotation for Travel Time of Next Shipping

(1) Introduction

From the survey regarding inland freight transport between landlocked country and seaport in central Asia[1)], border and seaport is sometimes to be as bottlenecks (sometimes called this as "border effects"[7)]) in terms of ST. It can be considered that in the same OD with VST, shippers would estimate ST of next trip based on their past experiences. Subsequently, they would make decision

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for departure time/day, route choice, seaport choice in mid-term period. Besides, information on VST is not normally provided to shippers, therefore, experiences of past shipping seem to have big impact on quotation on next ST. The modeling of quotation for ST of next trip has 2 purposes. First one is to show that shippers in developing countries made decision by using their experiences of past trips. Second one is to estimate quotation of ST of next shipping.

(2) Hölder Mean Approach[9)]

In general, in case developing transport behavior model, evaluation function of mean, maximum, minimum, weighted average value, etc. of factors expressing traveler's behavior mechanism are assumed. Nevertheless, traveler's behavior in real world is varied for place, scene, situation, etc. Thus, developing shipper's behavior, parameter estimation assuming solo-behavior mechanism seems to be straightforward. In this study, HM approach is applied for shipper's quotation for ST. A concept of HM is able to express several evaluation functions for different parameters estimated. The difference of each shipper's evaluation function can be incorporated in parameter. Aggregation operations in general can be expressed as following equation (1). Hölder Mean can express various means (e.g. geometric mean, harmonic mean, etc.) by using parameter α, showing following formula (2).

$$h : \lfloor x_1, x_2, \cdots, x_n \rfloor \rightarrow \bar{x} \tag{1}$$

$$\bar{x} = \left(\frac{x_1^{\alpha} + x_2^{\alpha} + \cdots + x_n^{\alpha}}{n} \right)^{\frac{1}{\alpha}} \tag{2}$$

Where α ($\alpha \neq 0$) denotes parameter. By using equation (2), several mean operations are allowed to take place as following Table 1.

Table 1 Mean Operation by Equation (2)

Condition	Equation	
a) Minimum value ($\alpha \rightarrow -\infty$)	$\bar{x}_{-\infty} = \min(x_1, x_2, \cdots, x_n)$	(3)
b) Harmonic mean ($\alpha \rightarrow -1$)	$\bar{x}_{-1} = \dfrac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}}$	(4)
c) Geometric mean ($\alpha \rightarrow 0$)	$\bar{x}_0 = (x_1 \cdot x_2 \cdot \cdots \cdot x_n)^{\frac{1}{n}}$	(5)
d) Arithmetic mean ($\alpha \rightarrow +1$)	$\bar{x}_{+1} = \dfrac{x_1 + x_2 + \cdots + x_n}{n}$	(6)
e) Maximum value ($\alpha \rightarrow +\infty$)	$\bar{x}_{+\infty} = \max(x_1, x_2, \cdots, x_n)$	(7)

(3) Model

In general, it can be supposed that traveler most-recent trip and 2nd most-recent trip do not have same importance for inferring TT of next shipping. Thus in this study, weighted HM formula, showing in (8), is applied so that express differences of each past shipping. An extra-waiting time at the border and seaport, which is important variables, is added for influencing shipper's preference. Unit value of free-flow traveling and delay (VST) has different value[9)]. Thus, ST on the link and on the node is separately considered as following.

$$TT_{next} = \sum_l \sum_b \sum_s A \cdot (w_{1,lbs} tt_{1,lbs}^{\alpha} + w_{2,lbs} tt_{2,lbs}^{\alpha} + \cdots + w_{3,lbs} tt_{n,lbs}^{\alpha} + w_{ord,lbs} tt_{ord,lbs}^{\alpha} + w_{\max,lbs} tt_{\max,lbs}^{\alpha})^{\frac{1}{\alpha}} + const.$$
$$\sum_{i=1}^{n} w_i = 1 \tag{8}$$

Where,

TT_{next}:	Quotation for following shipping time (hr)
$tt_{i,lbs}$:	Shipping time of shipping *i*th term before at link *l*, border *b* or seaport *s* (hr)
A:	Scale parameter

The smaller parameter α, short shipping time is weighted, whereas the higher parameter α, long shipping is weighted. The scale of parameter α is to be an indicator of importance of experiences for shippers. In case α is big, comparatively long shipping time is weighted for quotation of following shipping. Ordinal and maximum shipping time is also included as variable, which is so-called perception-shipping time[9].

(4) Application

Necessary data for parameter estimation can be done by questionnaire survey to shippers. Question would be shipping time experienced past n times. Number of n might be set arbitrary. Nevertheless, it should not be too large so that respondents answer properly. Regarding convergent calculation for parameter estimation, BFGS method would be able to be applied. Same trend of weighted coefficient of linear model and HM model was observed for traveler's trips to home country[9]. Thus, it can be considered that solution will not be converged to singular solution.

3. Semi-Dynamic Stochastic Shipper Equilibrium Model

(1) Purpose

In order to observe the effects of developed model, user equilibrium problem is considered. To do this, how much freight volume will be changed based on their choice comparing to current freight volume. Besides, an effect by improving a situation of border and seaport can be simulated. For example, total benefit of shipper and how many volume of freight would shift by reducing variability of waiting time at border would be quantitatively analyzed.

(2) Specification of Generalized Cost

Generalized Cost (GC) of route k compose of link cost and node cost. Node cost contains cost at the border and seaport mainly arising due to TT variability. GC can be formulated as equation (9);

$$GC_k^{rs} = \sum_{l \in k} LC_l + \sum_{b \in k} BC_b + \sum_{s \in k} SC_s \tag{9}$$

$$LC_l = LC\cos t_l \cdot D_l + vt_{shpr} \cdot LCtime_l + +VTTV_{shpr} \cdot Delay_l \tag{10}$$

$$BC_b = vt_{shpr} \cdot BCtime_b + VTTV_{shpr} \cdot Delay_b + PC_b \tag{11}$$

$$SC_s = vt_{shpr} \cdot SCtime_s + VTTV_{shpr} \cdot Delay_s + TC_s \tag{12}$$

where,
GC_k^{rs}: Generalized cost of route k between r and s (USD)
LC_l: Link cost of link l (USD)
BC_b: Border cost of border b (USD)
SC_s: Seaport cost of seaport s (USD/TEU)
$LCcost_l$: Unit shipping cost of link l (USD/TEU-km)
D_l: Distance of link l (km)
vt_{shpr}: value of time of shipper (USD/hr-TEU)
$LCtime_l$: Shipping time of link l (hr)
$BCtime_b$: Time at border b (hr)
$VTTV_{shpr}$: Value of travel time variability of shipper (USD/hr-TEU)
$Delay_i$: Delay at i (hr)
PC_b: Processing cost at the border b (USD)
TC_s: Terminal cost at the seaport s (USD)

Link cost consists of cost itself and time factor. Each cost is calculated using quotation of shipping time estimated by equation (8). As for cost at border and seaport, processing cost and terminal cost is considered respectively. Shippers are assumed to choose their route as minimizing the expected GC. GC contains STV since freight transport from landlocked countries to seaport (and vice versa) needs at least 1 border crossing which frequently gives delay. As a consequence of this uncertain event, increase in shippers cost would be observed. This cost is regarded as one of the Social Cost (SC)[10]. Estimating Value of Shipping Time Variability (VSTV), integrated approach[11] of Mean-Variance and Scheduling Approach would be used.

(3) Application

Stochastic User Equilibrium (SUM) Model is applied for freight volume assignment. In international logistics market, there are other agents than shippers (e.g. freight forwarder, terminal operator, carriers for land transport and seaport), nevertheless, this study assumes that shipper makes decision for route choice. Several studies[12-14] consider interdependency with foreign-going shipping company for seaport choice. However, this study omits this concept for simplification. Detail process and movement in the node (border and seaport) are omitted. Regarding the factors on the sea route, we treat this as homogenous. Therefore, it is assumed that every shipping company is able to use any berth in seaport. Shipper's route choice can be formulated as following;

$$f_k^{rs} = Q^{rs} \cdot \frac{\exp(-\theta \cdot GC_k^{rs})}{\sum_{k \in K_{rs}} \exp(-\theta \cdot GC_k^{rs})} \tag{14}$$

where, f_k^{rs}: Freight volume of route k of OD pair rs (TEU)

Q^{rs}: Freight volume of OD pair rs (TEU)

θ: Parameter

Freight volume between OD is given as centroid. As result of considering past experience including VST, it is assumed that choice for route by shippers would be changed if expected generalized cost of route k (route selected before) is higher than other route. However, in opposite case, shipper would not change their choice. In case expected generalized cost of next trip in route k is less than expected generalized cost in other route, and EGC in route k is higher than GC completed before, shipper would change just only departure time. Thus, in this context, this problem is to be semi-dynamic stochastic shipper equilibrium problem.

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