Estimating the market areas of railway stations: a case study of containers in Korea

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Abstract

Railway is an environmentally-friendly mode of transportation and has recently attracted more attention, not only from the practitioners, but also scholars from a sustainable freight transportation perspective. One of the important aspects that we need to know about railway's freight transportation is the size of market area (i.e. catchment area) of railway stations. Market area is needed to estimate transportation demand of commodities (i.e. O/D estimation). This study estimates the size of the market area of railway stations in the case of container transportation in Korea. Based on the interviews and surveys with carriers, factors contributing to the size of catchment areas are identified. In addition, the size of market areas under the various conditions are estimated and validated from the overall transportation perspective. The research results of this study are considered to be valuable in container O/D estimation and in marketing activities of container railway transportation.

Keywords: railway, market area, catchment area, container, freight transportation.

1 Introduction

Intermodal railway mode provides transportation service for consolidated loads such as containers and trailers by combining at least two modes [1]. According to economy of scale principles, therefore, the railway would be superior to road transportation in cost efficiency aspect. In addition it becomes an attractive

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alternative compared with trucking service because it alleviates traffic congestion and air pollution problems. Railway service is usually conducted by intermodal transportation, so there must be access/egress truck trip around railway stations. One of the important aspects, however, that we need to know about railway's freight transportation is the size of market area of railway stations. The market area of a departing railway station is the area where commodity produced at the area is transported by the railway station and the market area of an arriving railway station is the area where commodity arriving at the railway station is consumed.

This study is intended: i) to understand access/egress transportation behavior on railway freight stations based on the survey from carriers factors contributing to the size of catchment area are identified, ii) to estimate the size of railway stations' market area in the case of container transportation in Korea. The result of this study is considered to be valuable in container O/D estimation and in marketing activities of container railway transportation. In addition, it could contribute to determine the optimal size of market for freight facility location decisions.

2 Literature review

2.1 Access mode choice and catchment area of passenger's transportation service

Fwa *et al.* [2] analyzed car travel characteristics in Singapore using PDF approach. A vehicle based travel diary approach was adopted to collect the data. Trips were cross-classified and examined by trip purpose, time of travel, and road type. Lutin *et al.* [3] developed empirical models to identify transit service areas, in other words, the catchment areas for transit service. The study was directed towards the establishment of empirical tools for planning access to transit systems. Rama Moorthy [4] suggested a simplified procedure for determining light or rapid transit corridor or catchment area along with other factors such as mass transit demand, bus route generation, etc. The catchment areas for different modes of transit systems were determined basically for supporting the evaluation of other purposes of the study.

Tsamboulas *et al.* [5] implied disaggregate multinomial logit models for the analysis of the behavior of metro users in choosing their access modes to a metro stations in Greater Athens Area. A population segmentation approach was adopted and models referring to individuals having the same set of alternative access modes were developed. Trip purpose was found out to have significant effects on access mode choice. Loutzenheiser [6] developed logit model of walk access trips for Bay Area Rapid Transit (BART) Stations. The logit and regression models were combined together to analyze the choice probability of walk mode over other available modes. Three different models were developed for this study. The access mode choice set was composed of walk, bicycle, bus, car and others.

Fan *et al.* [7] applied logit model approach to model access mode and station choice by commuters for morning peak period work trip in the Greater Toronto, Ontario. Different models were developed for these different purposes. For analysis of station choice behavior multinomial logit modeling approach was applied while to analyze station access mode choice and station together, nested logit models were developed. Forinash and Koppelman [8] applied nested logit modeling approach to analyze the business travel in the Ontario-Quebec corridor of Canada. A set of nested logit structures allowing the differential sensitivity to changes in service quality of rail was estimated. Park *et al.* [9] analyzed the impacts of enhancement of access modes to main one using the water transportation in Bangkok, Thailand. In order to achieve this purpose, access mode choice behaviors were modeled using Probability Distribution Function (PDF), Multinomial Logit (MNL) and Nested Logit (NL) model. Lieshout [10] presented a novel methodology to access the size of airport catchment areas and the airport's market shares using a MNL passenger choice model. The developed method was applied to Amsterdam Schiphol airport in Netherland.

2.2 Catchment area of freight transportation

Nierat [11] applied the spatial theory, which was developed to determine the circumstances under which intermodal transport is competitive over trucking service, to the rail transportation market of France. By tracing the market area of rail terminals, the study identified the zones for which each mode is the most competitive. It also found which factors guarantee profitability for intermodal transport. The market area of a number of existing terminals was set up by questioning carriers. The results confirmed that the location relative to the terminals, the rail line-haul direction, and the length of the rail line-haul have the effect on the size of the intermodal rail terminal's market area.

Limbourg and Jourquin [12] developed a methodology in order to compare road and rail-road intermodal market areas that takes the network structures, the operation costs and location of the rail-road terminals into account. An analytical framework to model rail-road transport on hub-and-spoke networks was presented and applied using the trans-European networks of containers transportation service. The market area of an optimal eight hubs network configuration was presented both for the p-hub median and the p-hub center problem. It is considered that this paper considered the heterogeneity of space to determine the market area of rail-road terminal. In addition the paper has merits in that it compares the hub configurations obtained solving two hub location problems for the whole trans-European network.

3 Definition and estimation methods

3.1 Definition of intermodal railway transportation and market area

Figure 1 shows the intermodal transportation procedure of railway which consists of three transport steps: (i) from a production place to a departing railway station, (ii) from a departing railway station to an arriving railway station, and (iii) from an arriving railway station to a final consumption place. The two transportation steps of (i) and (ii) which are called as "access mode" and "egress mode", respectively are usually covered by truck. The railway transportation is referred as "intermodal transportation" because it intrinsically needs to be completed by truck for the two trips.

Figure 1: Railway intermodal transportation procedure.

The market area of a railway station is described in Figure 2. The market area of a departing railway station is the one where commodity produced at the area is transported by railway station and market area of an arriving railway station is the one where commodity arriving at the railway station is consumed.

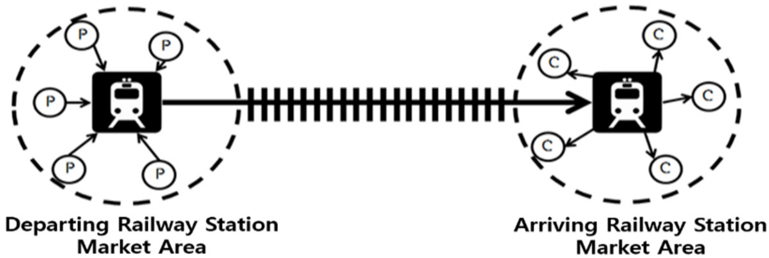


Figure 2: Market area of railway station.

3.2 Definition of market area: Nierat vs. generalized transportation cost concept

Nierat's [11] market area is based on the micro-economic analysis. Trucking and railway transportation are competing each other in the context of inland freight transportation. The shippers or carriers select a transport mode usually based on transport cost and transit time. The Nierat's study [11], however, assumed that shippers or carriers basically prefers cheaper mode in order to maximize profit.

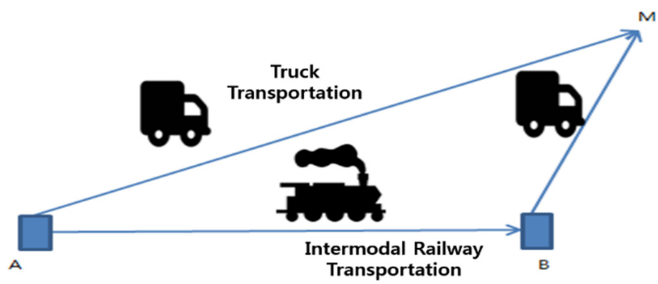


Figure 3: Comparing transportation mode.

In Figure 3 if a carrier transports a commodity from A from M, it has to compare the overall transportation costs of using truck and intermodal railway service. The transportation costs in Figure 3 are described by Figure 4 where transportation is conducted in the plane represented by X and Y axis while Z axis stands for the overall transportation costs of the two modes. The market area of railway station B is considered to be the one between M1 and M2 where the transportation cost of the intermodal railway is cheaper than that of the trucking service. In other words, market area of a railway station is defined as the one where the transportation cost of the intermodal railway is cheaper than that of the trucking service. However, in reality, not only transportation cost but also transportation time needs to be considered in the choice of transportation mode. Therefore this study newly define the concept of "generalized transportation cost" rather than "transportation cost" in order to determine a market area, which takes into account transportation cost and also transportation time.

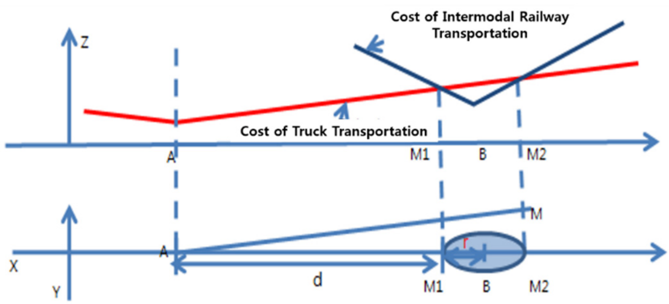


Figure 4: Concept of market area of railway service based on transportation cost.

The generalized transportation cost consists of two components of costs: monetary cost and transportation time. The transportation time is converted into monetary unit by multiplying "Value of Travel Time "(VOT) of eqn (1), which is based on the concept of "opportunity cost" of the transportation time from the context of economics. For example, if the transportation time and cost of a commodity between two points by railway are 6 hours and $1,000, respectively, and the value of travel time of the commodity is $50/hr, then the generalized transportation cost is $1,300 (transportation rate $1,000 + opportunity cost $300). The generalized transportation cost of a railway service includes not only the generalized transportation cost of the railway but also those of access and egress trucking services.

$$G_i = C_i + T_i \times VOT. \tag{1}$$

where:
G_i is generalized cost of transportation mode, i;
C_i is monetary cost of transportation mode, i;
T_i is opportunity cost of transportation mode, i;
VOT is value of travel time.

3.3 Estimation of transportation time and cost for truck and railway

This study estimated the unit transportation time and unit cost for truck and railway mode as shown in Table 1. For this the survey for fourteen carriers was conducted in October and November, 2013 [13]. The unit cost and transportation time of Table 1 includes all components of cost and time which are needed at the whole logistics process from the place of shipping(i.e. production or origin) to the place of arrival (i.e. consumption or destination). In Korea, truck rate usually includes loading and uploading cost therefore for truck mode, loading/uploading cost is not considered. The transportation cost and time of railway mode consists of cost and time for three different transportation legs: (i) from a production place to a departing railway station by truck, (ii) from a departing railway station to an arriving railway station by railway, and (iii) from an arriving railway station to a final consumption place by truck. In addition, loading/uploading costs and times which are occurred at the departing and arriving railway stations are added.

Table 1: The unit transportation time and cost of containers.

Transportation mode	Leg	Unit transportation time	Unit transportation cost
Trucking	Main-haul trip (direct transportation)	1.22 min/km	1,968 won/km
Intermodal railway	Access trip	1.22 min/km	12,250 won/km
	Main-haul trip	1.00 min.km	516 won/km
	Egress trip	1.22 min/km	11,359 won/km
	Loading/unloading	12 min/TEU	14,190 won/TEU

Source: 1) Lee *et al.* An estimation of value of time by road and rail freight transportation using factor cost analysis, *Journal of Transport Research*, The Korea Transport Institute, 2008 [14]. 2) Park *et al.*, Analyzing transportation characteristics of railway's container transportation, Korea Railroad Corporation, Daejeon, Korea, 2014 [13].

In Table 1, it may be seen that unit value of transportation costs of the trucking services for the intermodal railway service (i.e. trucking services for access and egress trips) are higher than those of the truck mode (i.e. 12,250 won/km for access truck trip and 11,359 won/km for egress truck trip vs. 1,968 won/km for truck mode). This pattern is attributed to the fact that the average distance of the main truck mode is a lot longer than those of the access and egress truck trips. The so called economies of scale in terms of transportation distance is therefore applied and accordingly lower unit value of cost can be achieved.

Transportation distance between railway stations was estimated using the railway database system of the Korea Railway Corporation (Korail). The transportation distance of truck was measured by the GIS data base of Korea Transportation Database (KTDB) which is an official data of Korea Transport Institute (KOTI). The values of travel time for truck and railway, which are needed to estimate the generalized transportation cost, were assumed to be 866.21 won/veh·hr (21,655.25 won/FEU·hr) based on the previous study by Park *et al.* [13] and Lee *et al.* [14].

3.4 Estimation of market area using cumulative probability density function

Market area of a railway station may be alternatively defined as access and egress distances of a truck mode from the railway station in order to start/complete intermodal railway transportation of containers. There may be so many number of access and egress truck trips from a railway station. Cumulative probability density function is used to statistically capture the distributional characteristics of distances of access and egress truck trips and thereby to set the size of market area of a railway station. In this study, a cumulative probability of 85% is used to set the size of market area.

4 Result analysis

4.1 Category analysis

There are 53 railway stations which are used for container transportation in Korea. Almost all of the containers pass through Inland container depot (ICD) and/or sea ports in Korea because 99% of the containers are used for the transportation of imported and/or exported goods. There are railway stations in the vicinity of ICD and sea ports. KORAIL's container freight statistics shows that 78.05% (ICD: 28.19%, sea port: 49.86%) of container freight transported by railway service use some major railway station which is located at the vicinity area of ICD and sea ports. Market areas of these major railway stations may be different from the others. O-bong station, in particular, is the heaviest container railway station located nearby Uiwang ICD. So railway stations are categorized into three groups for estimating market area of them: (i) All railway stations being used for container transportation, (ii) O-bong station which is located in the vicinity of ICD, and (iii) the others except O-bong station. However, in reality, it is seen that container freight transportation of railway stations nearby sea ports is conducted between sea port and railway station. In other words, when a railway station in the vicinity of sea port performs as an arriving station, the final consumption place is the sea port nearby the arriving railway station. When a sea port is a production site, where is import containers' initial point, a railway station neighboring sea port is a departing station. This study, hence, assume that it is not necessary to estimate the market area of 21 railway stations in the nearby sea port. Table 2 shows the categorized list of railway stations.

Table 2: Categorized railway stations.

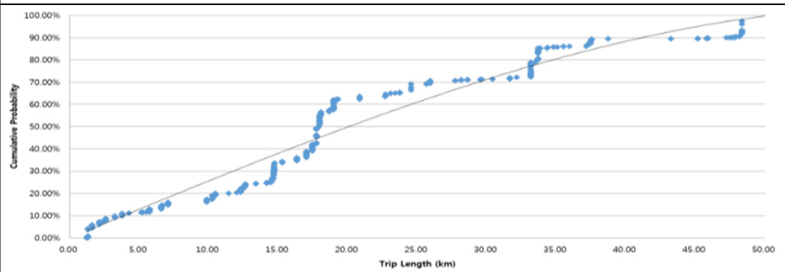
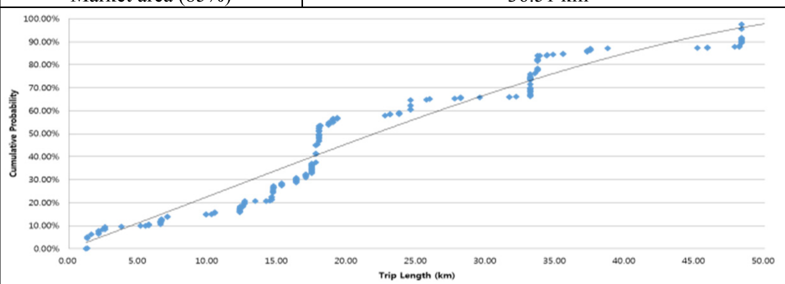
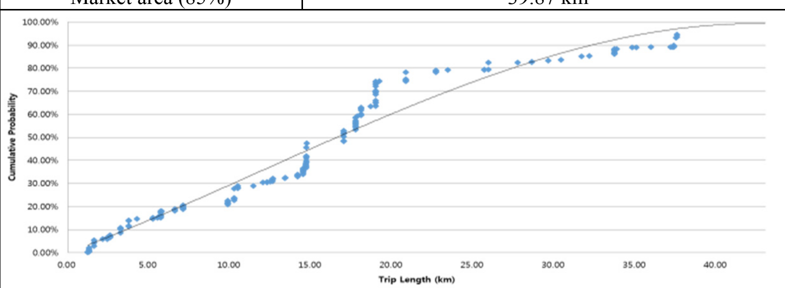
Group	Type of Stations (No. of stations)	Commodity Handled (TEU/year)
A	All Stations (32)	1,075,452
B	Stations nearby ICD (1)	597,976
C	The others except the station nearby ICD (31)	477,476

Source: Park *et al.*, Analyzing Transportation Characteristics of Railway's Container Transportation, Korea Railroad Corporation, Daejeon, Korea, 2014 [13].

4.2 Market area based on cumulative probability density function

Data on access/egress trip length and commodities flow were collected based on the survey for shippers and carriers. Table 3 shows the relation between cumulative container commodities flow (TEU/year) and access/egress trip length (km). The cumulative probability density functions are estimated for each categorized groups by using regression analysis. The size of market area on cumulative probability of 85% for each group is estimated: (i) 36.51 km for group A, (ii) 39.87 km for group B, and (iii) 28.55 km for group C. Most of business establishments are located in Seoul metropolitan and Gyeonggi province in Korea.

Table 3: Estimation result of market area based on cumulative probability density function.

Group		
A		
	Cumulative probability function	$y = 0.0258x + 4 \times 10^{-6}x^2 - 2 \times 10^{-6}x^3$ ($R^2 = 0.94$)
	Market area (85%)	36.51 km
B		
	Cumulative probability function	$y = 0.0221x + 10^{-4}x^2 - 3 \times 10^{-6}x^3$ ($R^2 = 0.93$)
	Market area (85%)	39.87 km
C		
	Cumulative probability function	$y = 0.0265x + 0.0004x^2 - 10^{-5}x^3$ ($R^2 = 0.96$)
	Market area (85%)	28.55 km

The O-bong railway station nearly Uiwang ICD is the biggest railway container facility to transport imported (or exported) containers from Seoul metropolitan and Gyeonggi province to sea port. This is because ICD provides export/import clearance work service and performs as logistics hub which enable shippers or carriers to use railway service. The economies of scale in terms of commodity quantity and facility size is applied so that cheaper and more frequent railway service can be offered. It is found that the market area of railway station in the vicinity of ICD is larger than that of other station according to the result of this study.

4.3 Comparison of empirical and theoretical market areas

Nierat's definition for determining market area of railway station is to search a threshold distance where the cost of railway intermodal transportation would be equal to the cost of trucking. The market area of railway station, thus, could be calculated with eqn (2).

$$\text{Market area(km)} = \frac{\text{Generalized cost of road(won) - Generalized cost of rail(won)}}{\text{Unit cost of access / egress transportation(won / km)}} \tag{2}$$

where:

generalized cost of road or rail = [Unit cost of road or rail (won/km) × Distance (km)] + [Travel time values of goods (won/TEU·time) × Distance (km)/Road or Rail transportation speed (km/h)] + [Loading and Unloading cost (won/frequency) × 2] + [Travel time values of goods (won/TEU·time) × Loading and Unloading time (time)].

Unit cost of access/egress transportation = Unit cost of access/egress (won/km) + [Travel time values of goods (won/TEU · time)/Road transportation speed (km/h)].

The results of Nierat's method and cumulative probability function method are named the theoretical market area and the empirical market area, respectively, in this paper. The market areas of railway station by each group based on two methods are shown in Table 4. In the group A, the theoretical size of market area is nearly identical to the empirical size. However, theoretical market area is larger than empirical one in the group B while theoretical market area is smaller than empirical one in the C group.

Table 4: Comparison of empirical and theoretical market areas.

Group	Theoretical market area (Nierat's method with generalized cost)	Empirical market area (Cumulative probability of 85%)
A	36.05 km	36.51 km
B	43.40 km	39.87 km
C	26.43 km	28.55 km

There are many decision elements affecting transportation modes choice. In this study, it is assumed that minimizing transportation cost and time bring about maximum utility to shippers or carriers. The result of theoretical analysis represents how far shippers or carriers could be attracted by railway intermodal transportation with respect to only time and cost. There are a lot of carriers and forwarders in the ICD who have right of decision-making to choose transportation modes. They could consider any other factor in order to select transportation mode in the real market. For example, a kind of long-term contracts, ownership of private trucks, and maintenance of business relationship among carriers, forwarders and shippers leads an irrational transportation just in terms of cost and time. In the survey interview, some carriers reveals that sometimes they choose trucking service because they make a freight agreement with private truck owners, which makes the real cost of trucking being discounted. It may suffice to say that there could be some other factors to influence transportation modes choice. These factors make the empirical market area differ from theoretical ones.

5 Discussion

Two estimation values, the size of theoretical and empirical market area, give two discussions: (i) what is the most appropriate cumulative probability to estimate empirical market area, and (ii) what else have impact on the transportation mode choice. In this study, the cumulative probability of 85% is used to set the size of market area because a sender (a production place) in the area with cumulative probability of from 85% to 100% is likely to use the railway station irregularly and it is reasonable to exclude this irregularity for estimating market area. However, there is no information available about how transportation modes choice behavior of shippers or carriers is varied with the distance to railway station. The farther away from the freight station shippers or carriers are located, the less frequently shippers or carriers use the railway service due to increased costs. In addition, there might be some other factors having impact on transportation modes choice such as frequency, service type, duration etc. As mentioned in result analysis, ownership of private truck or rights of using truck building on contract could affect transportation modes choice behavior. However, it is hard to quantify how much these factors influence on logistics decision making. On the surveys from carriers, we tried to collect data that provide a relation between these factors and mode choice. In this study, however, the relation between truck ownership and mode choice is excluded because of lack of data sample. Well-designed survey considering these aspects and further researches are needed.

6 Conclusion

Theoretical market area based on micro-economic theory and the empirical market area with cumulative probability of 85% using surveyed access/egress trip data are estimated in this study. The market area of railway station in the case of container freight is about 36 km. It is found that the results of two methods are approximately equal. When it comes to analysis of railway station neighboring ICD apart from other stations, though, theoretical market area is different from empirical ones. It is to be judged that there might be some other factors making this differentiation in this study. However, identifying factors having impact on transportation modes choice, except for cost and time, and quantitative relation between them are not easy. In addition, the 85% of cumulative probability was applied to estimate empirical market area in this study. It is considered that the results of this study may be useful for Korail when it estimates future transportation demand of containers under a various conditions.

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References

[1] European Commission, *EU Intermodal Transport: Key Statistical Data 1992-1999, European Commissions*, Office for Official Publications of European Communities, Luxembourg, 2002.

[2] Fwa T.F., Ang, B.W., and Ng, T.T., Study of Car Travel Characteristics in Singapore, Transportation research Record 1412, *Transportation Research Board*, National Research Council, Washington D.C., USA, pp. 1–9, 1993.

[3] Lutin, J.M., Liotine, M., and Ash, T.M., Empirical Models of Transit Service Areas, *Proc. of the American Society of Civil Engineers*, Transportation Engineering Journal of ASCE, **107(TE4)**, pp. 427–444, 1981.

[4] Rama Moorthy N.V., Planning of Integrated Transit Network for Bus and LRT, *Journal of Advanced Transportation*, **31(3)**, pp. 283–306, 1996.

[5] Tsamboulas, D., Golias, J., and Vlahoyannis, M., Model Development for Metro Station Access Mode Choice, *Transportation*, **19(3)**, pp. 231–244, 1992.

[6] Loutzenheiser, D.R., Pedestrian Access to Transit: Model of Walk Trips and Their Design and Urban Form Determinants Around Bay Area Rapid Transit Stations, Transportation Research Record 1604, *Transportation Research Board, National Research Council*, Washington, D.C., USA, pp. 40–49, 1997.

[7] Fan, K-S., Miller, E.J., and Badoe, D., Modeling Rail Access Mode and Station Choice, Transportation Research Record 1413, *Transportation Research Board*, National Research Council, Washington, D.C., USA, pp. 49–59, 1993.

[8] Forinash, C.V., and Koppelman, F.S., Application and Interpretation of Nested Logit Models of Intercity Mode Choice, Transportation research Record 1413, *Transportation Research Board*, National Research Council, Washington D.C., USA, pp. 98–106, 1992.

[9] Park, D., S. Lee, C. Kim, C. Choi, and C. Lee, Access Mode Choice Behaviors of Water Transportation: A Case of Bangkok, *Journal of Advanced Transportation*, **44(1)**, pp. 19–33, 2010.

[10] Lieshout, Measuring the Size of an Airport's Catchment Area, *Journal of Transport Geography*, **25**, pp. 27–34, 2012.

[11] Nierat, P., Market Area of Rail-Truck Terminals: Pertinence of the Spatial Theory, *Transportation Research-A*, **31(2)**, pp. 109–127, 1997.

[12] Limbourg, S. and B. Jourquin, Market Area of Intermodal Rail-Road Container Terminals Embedded in a Hub-and-Spoke Network, *Papers in Regional Science*, **89(1)**, pp. 135–154, 2010.

[13] Park, D., H. Kim, and S., Byun, Analyzing Transportation Characteristics of Railway's Container Transportation, Korea Railroad Corporation, Daejeon, Korea, 2014.

[14] Lee, Jang-Ho, Han, Sang-Yong., An estimation of value of time by road and rail freight transportation using factor cost analysis, *Journal of Transport Research*, The Korea Transport Institute, **15(2)**, pp. 1–16, 2008.