INTERNATIONAL COMPARISONS OF SOCIAL OVERHEAD CAPITAL STOCK: FOCUSED ON THE TRANSPORTATION SECTOR

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ABSTRACT

It has been an issue for the South Korean government to understand the sufficiency of its transportation infrastructure supply. One of the widely accepted ways to identify the proper amount of transportation infrastructure supply of a country is to compare the country's total amount to that of other countries, using indices such as total road length per capita or total road length per registered number of cars. The purpose of this study is to identify the problems of international comparisons based on these indices and to provide ideas that can help identify the reasonable amount of transportation infrastructure supply for a country. The study found that international comparisons through indices may result in very different outcomes depending on the indices applied. When total road length per square meter is used, South Korea is ranked below the average among the OECD member countries. However, the rank goes up to 3rd or higher when the comparison is conducted with total road length per capita. This study proposes an index for identifying a country's transportation infrastructure supply in the transportation sector with a "volume-to-capacity ratio". With the availability of international data for measuring volume-to-capacity ratio, the index would work as an appropriate measure since it considers both demand and supply of transportation capacity, particularly travel demand's behaviours responding to the limited capacity of the networks. The study concludes with ideas to enhance the indices, for example, reflecting the recent paradigm shift of the transportation policy that considers user satisfaction of the provided transportation services.

Keywords: transportation infrastructure supply, international comparisons.

1 INTRODUCTION

As the transportation infrastructure supply of South Korea has become close to that of developed countries in recent years, the Ministry of Strategy and Finance of Korea (MOSF) decided to gradually reduce the transportation infrastructure investment, on the basis that roadway length per square meter in Korea is the highest among the G20 countries (MOSF, 2015–2019 National Finance Operation Plan [1]). However, determining the sufficiency of transportation infrastructure supply based on simple comparisons could be inappropriate because one indicator does not comprehensively evaluate a country's ideal demand for transportation infrastructure supply. Thus, it is necessary to analyse the limitations of international comparisons and improve the methodology that correctly indicates the proper amount of infrastructure supply. The purpose of this study is to find out ways to objectively evaluate the level of transportation infrastructure supply of a country.

To this end, the paper sets the following goals. First, it reviews previous studies that attempted to evaluate transportation infrastructure supply and judges whether international comparisons can be used as a basis for future policy decision regarding infrastructure investment. Then, the paper suggests a way to improve the method of international comparisons to reflect the change of the transportation paradigm.

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2 LITERATURE REVIEW

2.1 Three approaches to measure the appropriateness of transportation infrastructure supply

There are three ways to measure transportation infrastructure supply; an econometric approach, international comparisons, and a transportation engineering approach. First, an econometric approach explains the role of transportation infrastructure investment based on production theory. Second, international comparisons measure the level of transportation infrastructure supply by comparing various indicators such as roadway length (km) per capita and roadway length (km) per square meter. Finally, a transportation engineering approach measures the level of service experienced by infrastructure users to judge the appropriateness of infrastructure supply.

In this section, we review existing studies on the above three aspects. First, an econometric approach finds appropriate infrastructure investment in relation to demand and supply. Park and Lee [2] constructed a cost function and an inverse demand function to find proper infrastructure investment based on the optimum at the point where marginal cost and marginal revenue intersect. They created an index to evaluate the degree of publicness of infrastructure and evaluated whether road, railway, port, and airport facilities were playing a role of public goods. This is based on the hypothesis that when a company pays an additional cost due to a lack of infrastructure investment, the infrastructure does not sufficiently play the role of public goods for production activities. On the other hand, Kim et al. [3] argued that it is difficult to measure transportation services because they are intangible. Therefore, it is not easy to estimate the equilibrium of transportation infrastructure supply based on the supply function and the demand function. The study estimates future transportation infrastructure demand by regression analysis for each sector (road, railway, port, airport) using income, population, trade size, and industrial structure. The study estimates infrastructure demand using the difference between the current infrastructure supply and the estimated future infrastructure demand.

Second, international comparisons are based on the hypothesis that the level of infrastructure investment in countries with similar conditions (economic size, land area, and income level) is comparable. Lee and Shin [4] compared the railroad investment of four OECD countries to that of South Korea with IRF [5] and World Bank data [6]. As a result, the level of railroad supply of South Korea was about 41.3% of those countries. However, international comparisons have various limitations because it uses a simple index which does not properly reflect the historic development infrastructure of a country. Index-based international comparisons generally end up with the inconsistent results that cannot be utilized as a strong basis for policy decision. There is a growing opinion that the results of international comparisons are difficult to be relied upon due to data credibility and limitations of data acquisition, and should be limited to consulting purposes only [7].

Finally, the appropriate level of infrastructure is often measured through a transportation engineering approach. Ahn et al. [8] investigated the development of the US infrastructure performance index, which considers both the quantitative and qualitative sides of infrastructure investment. This study was conducted as part of an effort to comprehensively evaluate infrastructure investment with various criteria, assuming that a clearer explanation can be made when various indicators of infrastructure investment are considered together.

3 METHODOLOGY

3.1 Considering interactions between demand and supply

This study suggests the simultaneous consideration of demand and supply for road infrastructure. A good example would be the volume-to-capacity ratio (V/C). It is considered that V/C can serve as an index reflecting the interactions between demand and supply in transportation network, if an estimate can be made through the model or through observed data.

Estimation for the V/C could be obtained by the travel demand model. By assigning the origin/destination trip table into the transportation network, the V/C for each road section can be computed. In case of Korea, the Korea Transport Database [10] provides the origin/destination trip table and the transportation network data that includes the basic information of roads such as the length, width, and the geo-spatial location and the associated the volume delay function (VDF).

Since the traffic assignment determines how each traveler selects his/her route to the destination considering the traffic congestion reflected on the VDF, the assigned traffic to the road network yields a hint for the usage of the road capacity. Generally, the traffic assignment adopts a principle Wardrop [9], that governs the travelers route choice behaviors in the network in such a way that no user may lower his travel time through unilateral action. This condition can be represented by the following equations

$$f_p^{rs}\left(c_p^{rs} - c_\pi^{rs}\right) = 0 \qquad \forall p \in p^{rs}, \forall rs, \tag{1}$$

$$c_p^{rs} - c_\pi^{rs} \geq 0 \qquad \forall p \in p^{rs}, \forall rs, \tag{2}$$

where, p^{rs} is the set of the paths connecting origin r, and destination s, and c_π^{rs} is the minimum travel time when a user traversing origin r, and destination s.

The number of traveller in the road link can be obtained by solving the following assignment problem.

$$\text{Min} = \text{Z} = \sum_a \int_0^{x_a} t_a(x_a)dx, \tag{3}$$

$$\text{subject to} \qquad \sum_p f_p^{rs} = q^{rs} \ : \ \forall\, r, s, \tag{4}$$

$$x_a = \sum_{r \in R, s \in S} \sum_{S_p \in P^{rs}} f_p^{rs} \delta_{a,p}^{rs} \ : \ \forall a, \tag{5}$$

$$f_p^{rs} \geq 0 : \forall p, r, s, \tag{6}$$

$$x_a \ \geq 0 : a \in A, \tag{7}$$

where, p is the path, q^{rs} is the travel demand originated from r and headed to destination s, x_a is the traffic flows in link a, t_a is the travel time on link a, and $\delta_{a,p}^{rs}$ is the incident variable having 1 if link a belongs to path p, otherwise zero.

Another way to calculate the interactions between demand and supply is to use the observed data. Rather than directly observe the traffic situation of the road, we can rely on the travel information data from the navigation information providing companies. However, this approach takes time to collect and to process the data.

This study chose the former one for calculating the interactions between demand and supply. The next paragraph shows the results.

4 RESULTS AND DISCUSSION

With the assigned traffic into the network (Fig. 1), the average V/C by roadway type is calculated, and the results are shown in Table 1. As shown in the table, the highest V/C ratio appears in the Seoul Metropolitan Area, followed by Busan and Daejeon.

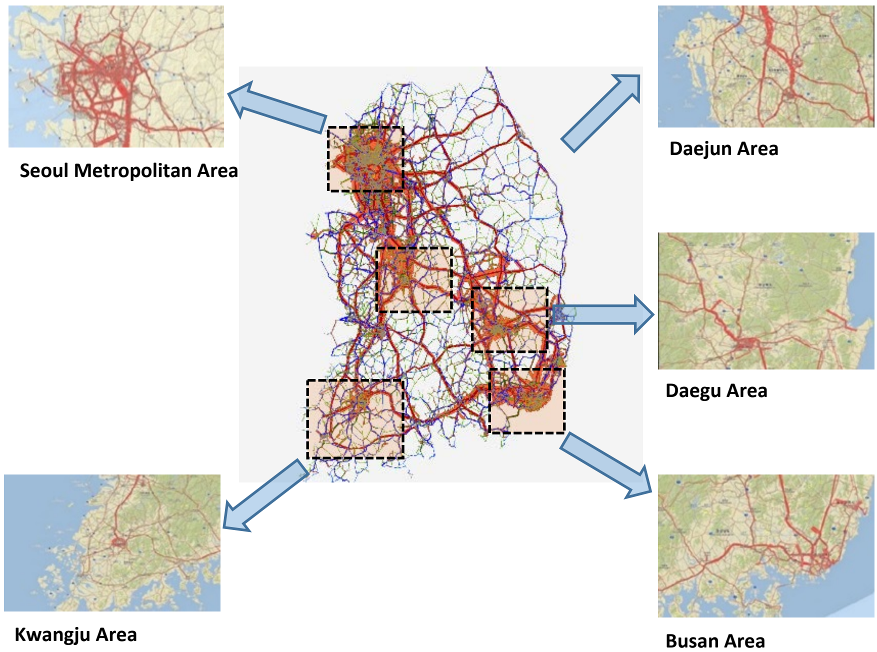


Figure 1: Congestion levels by region. (*Source: Yook et al, 2017.)*

Table 1: V/C by roadway type.

	Seoul metropolitan area	Busan metropolitan area	Daegu metropolitan area	Kwangju metropolitan area	Daejeon metropolitan area
National expressway	0.79	0.67	0.58	0.46	0.68
Expressway	0.82	0.88	0.62	0.27	0.39
General national road	0.59	0.46	0.27	0.26	0.36
Special city road	0.77	0.64	0.51	0.54	0.62
Local road	0.46	0.34	0.22	0.21	0.41
City road	0.51	0.37	0.32	0.32	0.35

Table 2: V/C improvement ratio.

	V/C	V/C improvement ratio (%)
National expressway	0.79	0.95
Expressway	0.82	0.90
General national road	0.59	0.87
Special city road	0.77	0.98
Local road	0.46	0.59
City road	0.51	0.76

V/C can be advanced to the marginal utility of infrastructure supply (V/C improvement rate). The marginal utility of infrastructure supply indicates how much congestion could be mitigated when infrastructure investment is made. It can be used as an indicator to measure the effects. The marginal utility of infrastructure supply can be defined as the "marginal V/C improvement ratio = increase/decrease of V/C by unit capacity increase" for marginal utility when expressed through V/C. The unit capacity increase is such that the investment corresponding to 1% of the total capacity of the road network is weighted by V/C of each link so that more capacity is provided in the congested region. This can be seen as an approach similar to the real-world investment policy in that policy decision on road investment is to solve the congestion-intensive section first. According to Table 2, V/C improvement ratio is estimated in a similar order to the current congestion V/C.

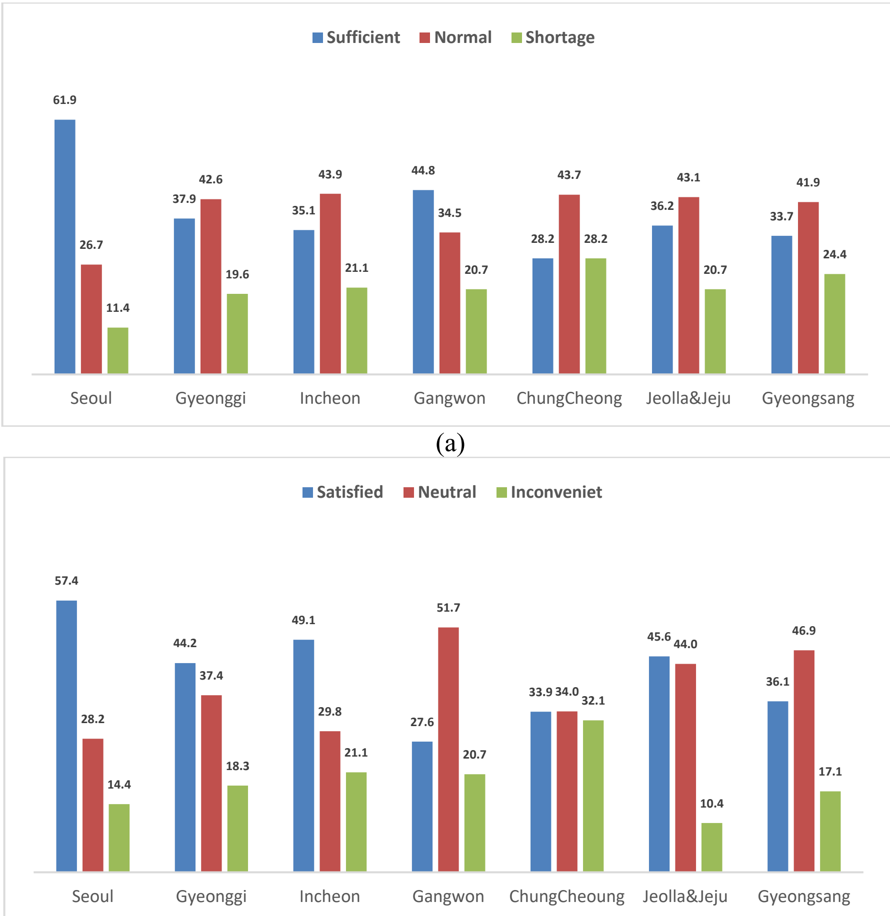
4.1 Discussion: need to consider the transportation paradigm shift

V/C is an index calculated based on the ratio of the traffic allocated to transportation infrastructure, which is advantageous because it can reflect the nonlinearity of V/C according to the demand increase and decrease. However, this does not consider the user's overall satisfaction. It does not suitably follow the changes of the transportation paradigm which emphasizes the quality improvement of transportation service.

According to Kim and Kim [11], in the metropolitan area with higher supply, satisfaction with service is higher than satisfaction with supply itself. On the other hand, Gangwon province shows that satisfaction with supply is higher than satisfaction with service (Fig. 2).

This indicates that the evaluation of supply criterion has insufficient consideration of the user side.

In addition, it is necessary to consider the qualitative aspects of infrastructure in terms of maintenance and management. If the maintenance and management are not done properly, the service level and the capacity that users experience can fall significantly. In the case of Korea, it is expected that the transportation facilities built in the early 90s will be aged within 20 years. As more traffic facilities exist, proper maintenance and management of them is very important to maintain the service level. Therefore, it is necessary to determine the quality of service provided to users through objective evaluation.



(a)

(b)

Figure 2: Survey on supply and user satisfaction by region. (a) Survey on the adequacy of transportation infrastructure supply by region; (b) Survey on the satisfaction level by region. (*Source: Kim et al, 2015.)*

5 CONCLUSIONS

Here are a few policy suggestions from the research. First, indicators based on international data contain many problems; therefore, the results of international comparisons should be limited to consulting purpose only in policy decision making. Rather than judging the appropriateness of infrastructure investment through comparisons with other countries, it is necessary to develop indicators that reflect the satisfaction of the users who use infrastructure. The second reflects the maintenance and management aspects. If maintenance and management are not done properly despite continuous supply of transportation facilities, the efficiency of use will be lowered due to user inconvenience capacity decline. In the case of South Korea which experienced a rapid supply of transportation infrastructure supply in a short period of time, proper maintenance and management are very important for managing the transportation service level. Therefore, it is necessary to establish transportation infrastructure investment policy with indicators that include a system for maintenance and management.

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