Commuting and Urban Spatial Structure for Reducing Carbon Dioxide Emission in Seoul City

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Abstract: Many researchers have concerned on relationship and interaction between urban spatial structure and transportation system, moreover, brought to advance debates on environmental burden. In this paper, we examine the reduction effect of carbon dioxide emission by assessing several scenarios which are about constructing subway infrastructure and reorganizing urban spatial structure. We find out which urban spatial structure is mostly valuable to reduce carbon dioxide emission. This result could be useful to draw up the policy direction of spatial structure.

Keywords: Commuting, Urban Spatial Structure, Carbon Dioxide Emission, Seoul City

1. Introduction

The issue of climate change has become a subject of intense interest all over the world since the last decade. The primary international policy framework against global warming is the United Nations Framework Convention on Climate Change (UNFCCC), specifically the Kyoto Protocol. In terms of the emphatic issue on preventing global warming is about reducing greenhouse gases. Expressly, it is essential to reduce the emission of carbon dioxide in handling climate change issue notably, because the emission of carbon dioxide is the largest contributing gas to the greenhouse effects. Hence, an effort for reduction is necessary to strive in the variety fields also as a matter of urban system.

The concern of environmental impacts caused by urban activities in urban system has been identified. Many researchers have concerned on relationship and interaction between urban spatial structure and transportation system, moreover, brought to advance debates on environmental burden or transportation energy efficiency. For example, a first body of literature is concerned with the analysis of commuting distance (or time) to seeking for the relationship between urban structure and change of commuting behavior empirically (Aguilera, 2005; Rouwendal et al, 1994; Wachs et al, 1993). A second body of literature brings out the concept of excess commuting or wasteful commuting that represents the difference between actual and minimized commuting when distributions of jobs and housing is given as the same as present situation (Frost et al, 1998; Giuliano and Small, 1993; Ma and Banister, 2007; Merriman et al, 1995; White, 1988). A third body of literature is focused on jobs-housing mismatch in urban area physically to measure job accessibility as an indicator of auto-oriented urban structure (Kawabata and Shen, 2006; Kawabata, 2009). These studies have generated much discussion about the relationship between jobs-housing balance and commuting behavior in various ways. Furthermore, these studies have tried to verify a hypothesis that a polycentric urban model could contribute to reducing commuting distance (or time) by allowing workers to locate within or close to their workplace. As the results, commuting could not occurred efficiently all the time, namely workers do not always make a journey to workplace just reducing their commuting distance for some reasons. A forth body of literature is to clarify the debate concerning about the negative environmental and energy effects caused by transportation system and related urban density (Bertolini and Clercq, 2003; Cervero, 2001; Lee and Suzuki, 2007; Mindali et al, 2004; Newman and Kenworthy, 1989). A lesson from these studies is commonly that energy consumption or environmental impact of urban transportation is negatively correlated with urban density. However, this is differently adopted into spatial hierarchy of urban area for example inner area and outer area. Additionally, some of approaches are modeled to integrate the effects of speed, acceleration, road grade and network, and also congestion to estimate the fuel consumption or emissions in relation to greenhouse gases (Frey H C et al, 2007; Nejadkoorki F et al, 2008; Scott D M et al,

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1997). Nevertheless, these studies are not consistent with urban system and just focused on efficient of road networks.

In these perspectives, more detailed planning policy line for future urban spatial structure with appropriate evaluation approach is necessary. The purpose of this study is to clarify a policy direction to head for planning and organizing urban spatial structure with a little environmental load for the future in Seoul City.

2. Study area and data set

The chosen study area for this study is Seoul City, Korea. The geographic unit applied is the smallest of administrative unit, named dong. Seoul City is divided into 522 dongs. The land area in Seoul City covers 605 square kilometer. In 2005 Seoul City accommodated 9,820 thousands peoples and that is occupied about a one-fifth of Korea, respectively, the number of workers is about 4,003 thousands (SK, 2005).

In this study, commuting (not to the other objective trips) is considered to examine the reduction of carbon dioxide emission by reorganizing residence and work places. The number of worker (commuter) among origin-to-destination (OD) is available from the 2002 Seoul Metropolitan Region Person Trip Survey (PT Survey) conducted by the Seoul Development Institute (SDI, 2002). OD travel time is available from the PT survey, but it is sample-based, thus travel time for a complete set of OD pairs is generally not available. In this study, we use Geographic Information System (GIS) to estimate the travel time and distance for journeys undertaken by automobile and subway. Moreover, a modal split model by applying a binary logit model is purposed to evaluate modal share. More information on the methodology how to evaluate OD travel times and modal share could be found in Lee and Suzuki's paper (2007).

To measure the emission of carbon dioxide by riding automobile and subway among ODs, a unit which is defined as an amount of emission when one person moves 1km according to different transportation mode is adopted. A unit of carbon dioxide emission is 150.7 g-CO_2 per person by 1km for automobile, and 17.9 g-CO_2 per person by 1km for subway, and these figures is referred a report that is issued to the Korea Transport Institute (Lee et al., 2005).

3. Scenarios set and results

3.1 Evaluation process

The process how we evaluate the reduction ratio of carbon dioxide emission is as follows. First, two models are adopted. The entropy maximization model is adopted to estimate the number of workers among all OD pairs when urban spatial structure, that is, distributions of workers' homes and workplaces, is changed (Wilson, 1967). However, the total commuting time is needed as a given factor in this model, so that we borrow the concept of excess commuting. That is why the commuting minimization model is adopted to measure excess commuting which is calculated by the discrepancy between actual and minimum average commuting time (White, 1988). The latter is obtained by solving the transportation problem using linear programming technique, while the distribution of homes and workplaces are constrained to be unchangeable.

Second, we assume that the value of excess commuting would be calculated about the same or less comparing to the current value even if the urban spatial structure is changed, and the factors that affect to the commuting patterns are not changed or fixed as same as the present situation. Consequently, excess commuting would be decreased if a strategy tends to promote jobs-housing balance. That is the reason that the present value of excess is assumed as an evaluation standard even though the urban spatial structure is reorganized. In each scenario, the total commuting time constraint in the entropy maximization model is determined by comparing the value of excess whether it is the same as the present value or not. If it is not the same, the total commuting time is set and calculate again.

Third, after that, the total carbon dioxide emission is calculated by the number of jobs and housing among OD pairs which is estimated by the Entropy Maximization Model. Then, the total carbon dioxide emission is compared to evaluate the effect of reorganizing urban spatial structure which one is more efficient to get rids of environmental burden.

3.2 Scenarios set

Scenarios are divided into two parts greatly. One part is for investing in construction of public transportation infrastructure, only subway and LRT is considered, without changing urban spatial structure. It evaluates the reduction effect of carbon dioxide emission by only maintenance and construction of the public transportation system. Two time periods in 2010 and 2020 are set.

The other part is only to reorganize urban spatial structure with a current transportation condition. Mainly four cases are set up: a) concentration / dispersion of jobs on urban, suburban or local centers, b) promotion of residence area in urban and suburban centers, c) promotion of developing area in near of station considering with jobs-housing balance, d) concentration on the number of jobs and residence in areas where is both urban and suburban centers, and also where is near subway station.

3.3 Results

The results are summarized as follows. First, about 4.5% in 2010 year, and 6.0% in 2020 year of carbon dioxide emission compare to the present commuting behavior could be reduced by newly equipping infrastructure of public transportation network. In other words, as the current urban spatial structure, some of carbon dioxide reduction is expected. We assume that the ratio of modal share is same as in 2002, even though the network is newly built. Consequently, the reduction ratio of carbon dioxide emission could be much larger than the result.

Second, the reduction ration of carbon dioxide emission, the case is, concentration or dispersion of jobs on urban, suburban or local centers, is calculated greater than the present condition. Moreover, the reduction ratio presents higher percentage when reorganized number of workers became big. The policy to make the strong urban and suburban centers is potentially to bring out the long journey from work to residence place, thus it makes the ratio of carbon dioxide emission is increased. In other words, depending on the commuting behavior could be occurred much worse conversely.

Third, the result of case, that is, promotion of residence area in urban and suburban centers, presented that 3% of total carbon dioxide emission decreased when about 2.4 % of workers in the place of residence in urban and suburban centers are reorganized. Indeed, the reduction ratio of carbon dioxide emission seems to grow big so that the number of workers in the place of residence becomes large portion. In other words, as for the policy of the residence promotion in urban center and suburban centers, the reduction effect was provided by shortening commuting to the work place.

Fourth, the largest reduction of carbon dioxide emission, the case is, promotion of developing area in near of station considering with jobs-housing balance, was presented. As a result, the biggest reduction is about 13.4% (the number of workers in the place of jobs and residence was about 3.78% and 5.16). It explains that the policy of promoting the area where is much convenient to access subway station (such as Transit-Oriented Development (TOD)) shows good side of effect to reduce environment impacts. Even though only small portion of number of workers in the place of residence and workplace is reorganized it provides the big portion of reduction.

Fifth, the result of case, that is, concentration on the number of jobs and residence in areas where is both urban and suburban centers, and also where is near subway station, also showed the reduction effect of carbon dioxide emission, however the reduction ratio is smaller than above the case, that is, promotion of developing area in near of station considering with jobs-housing balance. From this result, the policy of promoting the areas in near of subway station and in where is urban center or suburban centers have been also effective to reduce the emission of carbon dioxide.

4. Conclusions

In this paper, we examined the reduction effect of carbon dioxide emission by assessing several scenarios which are about constructing subway infrastructure and reorganizing urban spatial structure.

From the results, we could find the meaningful policy direction for drawing up urban spatial structure in terms of reducing carbon dioxide emission. First, long distance commuting could be reduced by promoting residential density where employment density is high. Second, the area where are accessibility to the station is good enough and especially modal share of subway is high as needed to develop mainly, it is needed to pick up the foothold area to promote chiefly where is convenient to access the subway station. In addition, jobs-housing balance of employment and residence is needed to be considered compositely.

Further research remains to be carried out. First, set scenarios in this study were quite simple based, because we tried to bring the direction of policy forth that how we need to draw up urban spatial structure for the future. Moreover, estimation for quantitative value of development in Seoul City is not simple. We need to consider of that with micro analysis. Second, the emission of carbon dioxide was considered as cost only. However, construction cost of subway infrastructure or cost for changing urban spatial structure are also important to be considered. All scenarios are needed to be assessed by reducing the total cost to compare the efficiency. In addition, the value for trade-off between cost and construction time are needed to analyze. Third, for the sake of simplicity only automobile and subway were considered. However, according to attain a more realistic analysis, it is necessary to consider other modes of transportation, especially given the high ratio of bus use in Seoul City.

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