Location of Commercial Facilities related to Desirable Urban Form

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Abstract

This study focuses on the deterioration of urban environment caused by increase in the rate of acceleration of motorization and dispersion of urban facilities which promotes motorization. Car traffic in urban areas is growing rapidly due to increasing car ownership and increase of total travel distance as a result of dispersion of urban facilities. In this study, in order to evaluate dispersion of urban facilities and change of urban environment, the Landuse-Transport-Environment Model presented. This model can demonstrate urban form, travel and environmental loads. In the landuse section, urban form is simulated using the Equilibrium Landuse Model. Substitution of equilibrium price for bid price for land currently in use is adopted in order to describe the competition between land activities in this model. In addition, the amount of trade in all zones is estimated by area of simulated commercial facilities using the Shopping Behavioral Model. In the transport section, traffic volume is estimated by the general four-step travel estimation procedure. In the environment section, three kinds of environmental loads are estimated as environmental loads from car traffic. Results of various single and combined policies are simulated using this model, and simulation results are discussed.
1 Introduction

Although comprehensive transport systems have been developed in a number of cities in Japan, many cities still have urban forms making cars indispensable. The reason why such cities have arisen, is due to rapid development of motorized transport and road improvement done in order to satisfy transport demand. As a result, these cities suffer from various problems.

From a global and urban environment point of view, automobiles consume much energy and discharge a large volume of exhaust gas. On the other hand, from an urban structural perspective, the dispersion of urban facilities, especially commercial facilities can be seen in such cities. As a result, the attractiveness of central urban areas has decreased and a number of central commercial districts have experienced economic decline. Thus it is clear that a dispersed urban form increases travel distance and generates more environmental loads.

The urban problems mentioned above can be divided into two categories. The first is being an increase in environmental loads generated by car traffic. The second is being a decrease in convenience of urban life as a result of the dispersed urban form. In order to solve the former problem, it is necessary to reduce the volume of car traffic. Urban and transport policies, such as compact city, improvement of public transportation and TDM, are effective for achieving this goal. To solve the latter problem, central commercial districts should be made more attractive by means of urban policy to control the location of urban facilities and improve public transportation networks. That urban form can be regarded as being friendly for elderly people, because they can travel without using private cars. However, from the viewpoint of commercial activities, the urban form where commercial activity is located along the trunk roads in suburban areas, is more effective for attracting consumers, and is economically efficient for managing stores.

There have been many studies about the environmental impact related to these problems [1]. [2]. [3], by changing urban form by way of sequential implementation of landuse and transport policy. However, it should be noted that it is necessary to evaluate change of location of commercial facilities to draft policies which are effective and for all activities.

In this study, the Landuse-Transport-Environment Model [4] which can evaluate urban and transport policies is presented and developed into a more flexible and comprehensive system so as to be able to evaluate improvement of commercial facilities as well as locations of such facilities. Urban policies are proposed in terms of the environment and convenience of urban life. The policies
are evaluated by simulation using the revised Landuse-Transport-Environment Model. In the evaluation of convenience of urban life, the Shopping Behavioral Model [5] which is derived based on the Utility Maximization Theory, is introduced.

2 Structure of Landuse-Transport-Environment Model

In this study, the Landuse-Transport-Environment Model is used as a base together with the Landuse-Transport Model [6] developed by the authors. The system we propose can be divided into the following three parts: the landuse model, estimation of transport demand and estimation of environmental loads sections respectively. Also, the Shopping Behavioral Model is included in the landuse model section as a sub model. A flowchart of this system is presented in Figure 1.

At first, urban policies, schemes and action plans are proposed aiming at improvement of the urban environment. Landuse pattern after implementation of such policies is predicted in the landuse model section. Next, for estimation of transport demand, the model predicts traffic patterns based on the landuse pattern.
Finally, in the estimation of environmental loads section, environmental loads such as air pollution, noise and vibration, are estimated based on traffic patterns. This model makes it possible to consider various kinds of urban policies. Therefore, it is possible to evaluate the urban environment after implementation of various kinds of urban policies.

2.1 Land use model

In this model, in order to simulate urban landuse after implementation of urban policies, an equilibrium landuse model is derived based on the urban economic hypothesis. The characteristics of this landuse model are outlined as follows.

1) For locational behavior of each activity, it is assumed that people behave in such a way to maximize their personal utility, and can thus be represented as a logit model.

2) Three activities are considered in this landuse model. They are residential, commercial and land supplier activities.

3) Regarding behavior of land suppliers, it can be assumed that they supply their land depending on land price. Based on this assumption, the supply model of land is developed [7].

4) The land market is based on the theoretical framework of Walrasian general markets equilibrium.

5) In order to describe the competition between activities when they seek land, a substitute equilibrium price for bid price on currently in use is adopted [8].

2.2 Estimation method of transport demand

In this study, the four-step travel procedure is used as a traffic demand prediction model. First, generation and attraction models are developed for the following four travel purposes: commuting, business, returning home and others. Here, the generator method and function models are employed. The traffic generation and attraction models, which can estimate each time-period for the four travel purposes, are constructed. Next, the gravity model is applied to the trip distribution model. Finally, car traffic between zones is assigned to road links using the Incremental Assignment Method. By this analysis, traffic volume in each link, according to car-type, travel time along with average speed of cars are obtained.
2.3 Estimation method for environmental loads

In order to evaluate the influence of change of urban form, environmental loads from car traffic are estimated in the estimation of environmental loads section. The three kinds of environmental load; air pollution, noise and vibration, are estimated in this section. Environmental loads are estimated for 100m × 100m meshes in urban areas, and estimation models of each environmental load are made referring the manual for assessment of road improvement.

3 Application of Landuse-Transport-Environment Model

3.1 Outline of Tokushima-City

Tokushima-City was selected as the case study area. Tokushima-City, with an area of 190km² and a population of 270,000, is the capital city of Tokushima Prefecture, and is the center of the region for politics, economics, culture and so on. Tokushima is a typical rural city in Japan. As thousands of workers in Tokushima live in towns surrounding the city, and most of them commute by car due to inconvenience of the public transportation system as well as serious traffic congestion occurs in the city center and its fringe areas. In recent years, in Tokushima-City’s urban area including Tokushima-City, road improvement to keep up with the rapid increase of motorized traffic, has been progressing. Big and middle-sized shopping centers have begun to appear in suburban roadside areas and, as a result, it may be a problem that promoting such commercial locations will bring about a dispersion of urban facilities. In fact, for example, some large-size retailers have withdrawn from the city center, and shopping activities in the shopping mall in the city center continues to decline.

3.2 Policies to improve urban environment

In Tokushima-City’s urban area, commercial facilities are located in suburban
roadside areas to attract car drivers following road improvement. Commercial facilities in such locations bring about an economic decline in shopping malls in the city center, and assume that customers will come to shop in suburban areas by car. The location of commercial facilities also results in increased travel distance by cars in urban areas.

From the viewpoint of urban environment, it can be thought to be beneficial to restrict construction of commercial facilities in suburban roadside areas and to provide incentives for commercial facilities to move to shopping malls in the city center. Along with this, improvement of the public transportation network is also necessary. However, the present public transportation network in the Tokushima-City urban area lacks attractiveness for transport users in urban areas. In order to improve the public transportation network up to such a level where people will use public rather than private transport, a large amount of investment with a long period of time is required. In addition, from the viewpoint of commercial facilities, retailers will have disadvantages in management when commercial facilities are restricted to locate in suburban areas.

With the above in mind, in this study, various patterns of urban form by are simulated by implementation of policies, such as, concentration of commercial facilities to city center location of such facilities in suburban areas by incentive and promotion of location, and soon. Moreover, the results of simulations after the implementation of combined policies described above are analyzed, and which urban form is desirable for the urban environment and commercial activities is examined.

4 Simulation

In this simulation, 1997 is taken to be the present year and 2010 is taken to be a future prediction year. Change of urban form between these years is simulated both with and without implementation of policies.

4.1 Regional zoning and mesh system

The regional zoning and mesh system of the Landuse-Transport-Environment Model are outlined.

In the landuse model section, first, the area of Tokushima-City is divided into 23 zones. Activities are allocated to 23 zones as a first step. Next, to analyze in more detail, the original 23 zones are divided into 72 zones, where activities of each of the 23 of the zones are allocated to the 72 zones. In the estimation of
transport demand section, 7 new large zones in areas out of Tokushima-City are added to the existing 72 zones in the city. This is due to there being a large volume of traffic between the cities and surrounding regions. In the estimation of environmental loads section, the area of Tokushima-City is divided into 18,400 segments of 100m × 100m meshes, and environmental loads are estimated for each mesh segment.

4.2 Simulation pattern

Three kinds of urban policies are considered in this simulation. Details of each policy are explained below.
(Policy 1) Road improvement: This policy assumes that all of the roads currently planned, including Tokushima ring road which was planned in order to solve problems such as road congestion in the city center and promotion of the economic revival of Tokushima-City, are completed.
(Policy 2) Commercial policy: This policy changes location of commercial facilities along with distribution of employees in urban areas and sales volume of each zone. For this policy, two contrasting policies, which are, (2a) having incentives for commercial facilities to move to the city center, and (2b) offering incentives for commercial facilities to move to suburban roadside areas, are considered. The city center, suburban roadside areas and other areas in Tokushima-City are shown in figure 2.
(Policy 3) Residential policy: This policy aims at the conversion of the urban from to the compact city form by utilizing vacant land in the center of a city for construction of multi-story residencies.

As a result of simulation without any policy in 2010, it showed a 38.5% increase in total travel time of car traffic and an 11.8% decrease in average speed compared with that of 1997. With regard to traffic volume of each link, traffic exceeded flow capacity into trunk roads during peak time periods of commuting and returning home traffic in the morning and evening respectively. This result shows that it is necessary to improve the road network in Tokushima-City's urban area before 2010. Hence, in this study, road improvement as a prerequisite condition for the combination of policies was considered. Combinations of policies simulated are shown in table 1.
Table 1 Combination of policies

<table>
<thead>
<tr>
<th>Simulation case</th>
<th>Combination of policies</th>
<th>Implemented policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Policy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 1</td>
<td>Policy 1</td>
<td>○</td>
</tr>
<tr>
<td>Case 2</td>
<td>Policy 1+2a</td>
<td>○</td>
</tr>
<tr>
<td>Case 3</td>
<td>Policy 1+2a+3</td>
<td>○</td>
</tr>
<tr>
<td>Case 4</td>
<td>Policy 1+2b</td>
<td>○</td>
</tr>
</tbody>
</table>

5 Results of Simulation

5.1 Results of sales volume

Figure 3 shows sales volume results of each simulation case. Comparing that results, between without case and case 1, and between without case and case 4, in short, between providing incentives to move to the city center and promotion of suburban roadside location, there is difference in rate of change in sales. This is because the ratio of floor area to land space of commercial facilities (floor ratio) is different in each zone. The floor ratio in the city center is higher than in suburban areas. There are few car parks, and the buildings are multistory in parts of the city center. On the other hand, there are large-scale car parks to attract car-using customers, and low story facilities due to low land price in suburban areas.

![Figure 3 Share of sales volume between regions](image-url)
From the results of case 2 and case 3, sales volume of the city center is slightly increased, and that for suburban roadside zones and the other zones decreased. This is due to concentration of population in the city center and shopping for daily necessities being concentrated in the city center. Besides, sales volume of other zones of case 1 is greater than that of case 4. This is why there is a decrease of attractiveness of the city center due to promotion of suburban areas, and an increase in attractiveness of other zones.

5.2 Results of transport

Table 2 shows transport results of each simulation case. From these results, it is clear that road improvement is effective for improving transportation conditions. There is no difference between transportation conditions even with implementation of commercial policies (case 2 & case 4). With regard to residential policy, population is concentrated in the city center, as a result average traffic speed improves. Thus, it can be said that road improvement is the most effective means to improve transportation condition. But, it is necessary to implement combined policies such as “hard-means” like road improvement with “soft-means” like urban policy and transport demand management.

<table>
<thead>
<tr>
<th>Simulation case</th>
<th>Total travel time (million hours)</th>
<th>Average speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without policy</td>
<td>2.10 (0%)</td>
<td>24.3 (0%)</td>
</tr>
<tr>
<td>Case 1</td>
<td>1.83 (-12.8%)</td>
<td>29.3 (20.6%)</td>
</tr>
<tr>
<td>Case 2</td>
<td>1.83 (-12.8%)</td>
<td>29.4 (20.6%)</td>
</tr>
<tr>
<td>Case 3</td>
<td>1.83 (-12.8%)</td>
<td>30.1 (23.3%)</td>
</tr>
<tr>
<td>Case 4</td>
<td>1.83 (-12.9%)</td>
<td>29.4 (20.7%)</td>
</tr>
</tbody>
</table>

5.3 Results of environment

5.3.1 Environmental load results

Table 3 presents results of each simulation case, showing the percentage of the number of meshes where environmental load of air pollution, noise and vibration exceeded environmental limits decided by the government. It appears that before and after road improvement, air pollution (NO₂) load is drastically reduced, but noise and vibration loads rise a little. This result is due to changing of traffic speed of each link. In the case without policy (before road improvement), traffic speed is
low as traffic volume exceeds the traffic capacity of each link. In such a condition, cars generate much air pollution, but such a low speed reduces generation of noise and vibration. Therefore, regarding relationships between air pollution and noise as well as between air pollution and vibration, there is in conflict as one environmental load is reduced, another environmental load is increased. Looking at the simulation results, changing rate of noise and vibration loads has little effect on air pollution load. So it can be said that the urban environment after road improvement is improved when the urban environment is assessed as a whole.

The rate of change of environmental loads after implementation of residential and commercial policy is a little when the environment is evaluated in all urban areas. However, such policies change urban form and consequently change distribution of population and employees, so it is necessary to evaluate environmental loads from the viewpoint of their spatial distribution.

<table>
<thead>
<tr>
<th>Simulation case</th>
<th>Percentage exceeding that of environmental standard (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO2</td>
</tr>
<tr>
<td></td>
<td>Day time</td>
</tr>
<tr>
<td>Without policy</td>
<td>16.76</td>
</tr>
<tr>
<td>Case 1</td>
<td>5.92</td>
</tr>
<tr>
<td>Case 2</td>
<td>5.93</td>
</tr>
<tr>
<td>Case 3</td>
<td>5.83</td>
</tr>
<tr>
<td>Case 4</td>
<td>5.95</td>
</tr>
</tbody>
</table>

**5.3.2 Population who live in areas exceeding the environmental load limit**

Table 4 shows population who live in areas exceeding environmental pollution limits stipulated by the government. The population of Tokushima-City in 2010 will be approximately 280,000. These results are almost the same as the environment results (Table 3). A notable result is evident in case 3 where the population who live in areas exceeding the environmental limits actually increased. The reason for this is due to residents in urban areas being concentrated into the center region where there is the greatest level of pollution. Thus it is necessary to consider this point when designing residential policy.
Table 4 Population who live in exceeding environmental limit areas

<table>
<thead>
<tr>
<th>Simulation case</th>
<th>People in exceeding environmental limit areas (thousands of people)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>Without policy</td>
<td>100.03</td>
</tr>
<tr>
<td>Case 1</td>
<td>29.42</td>
</tr>
<tr>
<td>Case 2</td>
<td>29.67</td>
</tr>
<tr>
<td>Case 3</td>
<td>33.06</td>
</tr>
<tr>
<td>Case 4</td>
<td>30.15</td>
</tr>
</tbody>
</table>

6 Conclusion

In this study, first, the Landuse-Transport-Environment Model was developed to evaluate commercial policy, and a number of patterns of assumed urban form were simulated. Moreover, not only one evaluation value was considered, but also results of each simulation case from a variety of angles such as landuse, transportation and environmental results. The main findings of this study are as follows:

(1) Residential, commercial activities and land supplier are considered as activities of the Landuse Model. Competition among land activities is described as equilibrium land price settled in the land market. Difference of sales volume, before and after implementation of policy was estimated by application of shopping behavioral model. As a result, it was shown that the policy incentive to move to the city center, where the market was originally large and floor space is high, is more influential than promoting suburban roadside locations.

(2) It was shown that road improvement is indispensable in order to keep up with increasing traffic demand in the future for Tokushima-City. Difficulty of improvement of the urban environment by implementation of residential and commercial policy was also shown.

(3) The most effective policy to improve environmental load is road improvement, which improves traffic condition. Improvement of the traffic condition, results in rising traffic speed, and consequently, air pollution is improved by this policy, although noise and vibration pollution become worse. As the relationship between air pollution, noise and vibration can be said to be in conflict, both urban policy and improvement of road structure are required to cope with these kinds of pollution. The result of simulation of case 3 shows that the policy, like compact city, improves the whole urban environment slightly, although this policy concentrates the population into the city center where severe environmental loads exist. Thus, it is necessary to consider this point when designing urban policy.

(4) Desirable urban form which was discussed in this study, was realized without
commercial and residential policies in the Tokushima-City’s urban area, because only a small proportion of the population suffered from environmental loads from road traffic. But, it is assumed that when road improvement were finished, it would bring about location of commercial facilities to suburban roadside areas rapidly exceeding the results estimated here. In addition, such urban forms cause other problems such as adversely effecting traffic safety and urban scenery. So, in order to realize desirable urban form, it is considered that it is necessary to apply a variety of measures.

References


