An Urban Environment Analysis System based on an Integrated Land-Use and Transport Model

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Abstract

During last several decades the world population continued to grow at an exponential rate, supported mainly by the improved health care facilities all over the world. But most of this growth was confined to relatively fewer number of urban centres. This trend was more obvious in the metropolitan areas of developing countries, where already high natural population increases were backed by increasing migration from rural areas. These intolerably high population growths, however, were not paralleled by the infrastructure provision, and the inevitable outcome was the numerous land-use, transport and environment related problems. The magnitude and the complexity of urban problems in metropolitan areas of developing countries reveal the extent to which these sectors of the metropolis are interrelated. The interrelationships between these sectors are so significant that the roots of the problems in one sector lie in the other sectors as well, and hence should be handled with an integrated approach. Unfortunately, the current institutional set up or the practice of urban planning does not facilitate policy formulation and implementation with such integrated approach.

One of the pre-requisites for this much-needed co-ordinated institutional set up and policy planning and implementation practice is an analysis tool that covers all these sectors and the interrelationships among them. An analysis system for integrated policies of land-use, transport and the environment has the objective of providing such an analysis tool. This research focuses mainly on the development of an urban environment analysis system based on an integrated land-use and transport model.

This study deals especially with developing metropolises, and those in the Southeast Asia in particular. The objectives of the study are; understanding the present situation and issues of the developing metropolitan areas; the theoretical development of an integrated land-use and transport model; the development of an estimation system of land-use and the environment; and development of a personal computer based analysis system for integrated policies of land-use, transport and the environment.

In the beginning, investigation is made on the present situations of

developing metropolises with regard to land-use, transport and the environment, in an attempt to understand the issues and their interrelationships, and to decide on the kind of integration between land-use, transport and the environment that best suits the urban areas under discussion.

The ways of modelling interactions between land-use and transport are formed considering the dynamics of land-use change and trip characteristics. Land-use and transport interaction is represented in two ways in the contemporary urban models; interaction type where land-use and transport are represented hierarchically connected separate modules, and integrated type where land-use and transport are represented in an organically connected single model framework. The two kinds of integration are discussed and compared.

Some urban environmental issues pertinent to the developing metropolises, which have some significance at finer spatial levels than the whole metropolis, are identified and discussed in detail. Most of these issues can be identified as externalities of land-use and transport. The environmental estimation is therefore based on the land-use and transport forecast from the integrated land-use and transport model. The interaction between transport and the environment have been the subject of many researches and at present there are many good environment estimation models to forecast transport externalities. But little research has been conducted on the environmental impacts of land-use. Although the environmental impacts of transport are very important, impacts of land-use, such as solid waste and waste water problem, are not at all insignificant, especially in developing metropolises.

In the development of the environment estimation system here, interactions between land-use and the environment are discussed. Because the environment estimation model is intended to be used together with an integrated land-use and transport model (which itself is based on an improved version of the RURBAN (Random Utility Rent-Bidding ANalysis) land-use model), it is considered to be necessary to use predicted land-use and transport conditions as inputs, and environment qualities that form explanatory variables for land-use forecast as some of the outputs.

In the development of the estimation system of urban land-use and the environment, environmental impacts of land-use are classified into those depend on the change of land-cover and those depend on the intensity of land-use

activities. Land cover dependent environmental impacts can be estimated if the land-cover change is known, whereas for other impacts the land-use activity intensity should be known.

The basic assumption behind the land cover and emission estimation is that both the land cover and the emission rate of pollutants are related to the land price of the area, which is an output from the land-use model. Land price is used here to represent the intensity of urban activities taking place in a given zone. Out of the zone characteristics predicted by the land-use simulation model, land price represents the intensity of activities most. Since the environmental estimation system is developed to be used together with a land-use simulation model, land price is selected as an index of activity intensity. Land cover does not mean the land-use of an area but the 'spatial composition of land according to the land cover types, such as vegetation, water bodies or built-up areas, as defined in the remote-sensing information'. Whereas emission rates are defined as 'the amount of pollutant emission in a given time from a unit of locator group'. The relationships that relate land cover compositions and emission rates with the land price are developed empirically using base year data of sampled zones. The empirical relationships developed using sampled data are used to forecast the land cover compositions and emission rates of a zone with a known land price. Land cover and emission rates for the forecast year, are used together with land-use activity data, derived from the locator composition, and other topographic data, in the environmental simulation model to estimate environmental indicators for different zones.

An empirical study is carried out to investigate to what extent is valid the assumption that the emission rates, which represent the intensity of activities in a zone, are related to the land price. Ward-wise solid waste emission data during 1987 and 1990 in the city of Yokohama for residential land-use agree with the assumption. The emission rates and the land price are related with correlation coefficient (R^2) of between 0.32 and 0.57. These low correlations are, however, found to be due to the high land prices in two of the wards, which actually have more relationship with the Tokyo metropolis than with Yokohama. The exclusion of these two wards increase the correlation coefficient to 0.95. However, it is found that the per capita pollutant emission relates better with the land price, than the pollutant emission per household, in the case of residential land-use. Example

emission equations are derived to estimate solid waste generation from the residential land-use.

Another empirical study is carried out to examine the relationship between the land cover composition and the land price. Aerial photographic information and land prices of 1990 in the City of Yokohama are used. Land blocks with varying land prices and belong to different land-uses are used in the analysis. Land cover types are identified visually from the aerial photographs. These land cover compositions correlate with the land price, with correlation coefficients (R^2) varying between 0.5 and 0.8. An example set of share curves, which represent the relationships between land price and the composition of land covers, are developed using the data, for different land-use categories.

A personal computer based analysis system for integrated policies of land-use, transport and the environment is developed based on the integrated land-use and transport model and the urban environment analysis system mentioned above. The latter part of the study discusses the development of this analysis system on MS-Windows 3.1 environment using Visual BASIC 3.0 as the user interface and FORTRAN language for simulation programs. A brief explanation about the basic features, the facilities available, and the kind of visual output presentation available in the system is also given.

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