Introduction of Land Use Model to Improve Travel Demand Forecasting in a Metropolitan Area: Case of TRANUS Application to Sapporo

Chapter 4

Introduction of Land Use Model to Improve Travel Demand Forecasting in a Metropolitan Area: Case of TRANUS Application to Sapporo

Varameth Vichiensan
Kazuaki Miyamoto
Katsuya Sato
Keiichi Kitazume

Abstract: Travel demand forecasting is one of the most essential steps in the master transportation plan as well as individual infrastructure development projects. The forecast is usually made by the conventional four-step transportation model, in which the future land-use (in terms of socioeconomics) is a given input. This implies that interactions between land-use and transportation are totally neglected. It is considered that inaccurate input (socioeconomic forecast) is a primary source of inaccuracy of the travel demand forecast. Therefore, this paper presents, with an empirical result, the benefit of introducing land-use model into travel demand forecasting. The discussion is based on the result of TRANUS model application to Sapporo metropolitan area of Japan. TRANUS is a typical land-use/transportation model, which models the impact of transportation to the future land-use. A case study of with/without analysis shows that the new subway section has a substantially large impact to the future land-use. This evidence implies that land-use/transportation interaction must not be neglected in the modeling and analysis. Moreover, the fare comparison shows that the forecast made by the TRANUS Sapporo is more accurate than the PT forecast.

1. INTRODUCTION

Travel demand forecasting is one of the most essential steps in the master transportation planning as well as in the individual infrastructure development project. However, the forecasts are not always satisfactory when it is compared with the real travel demand after the projects/plans have been implemented. Moreover, the forecasting procedures are requested to have higher ability to respond to the changing lifestyles, social concerns, and a wide range of policies and policy measures. This is due to the emerging concern on the environment of air pollution and global warming. Many countries have required that land-use must be recognized in the integrated planning and analysis. It is learned that land-use models are being used in the travel demand forecasting procedure (Miyamoto *et.al.*, 2000). This paper presents the benefit of introducing land-use model into the travel demand forecasting, with the empirical results from the TRANUS Sapporo model. The rest of this paper is structured as follows. Section 2 describes the design and implementation of TRANUS Sapporo. Section 3 identifies the cause of error of the travel demand forecast, which may be reduced by means of using the land-use model. Section 4 shows why we need to consider land-use/transportation interaction in the integrated plan and analysis with the empirical result. Section 5 claims that the forecast made by land-use model is more accurate than the conventional forecast. Finally Section 6 concludes the paper with some remarks.

2. TRANUS MODEL OF SAPPORO METROPOLITAN

Developed by De la Barra (1989), TRANUS is one of a few operational models that are really used in the practical urban modeling (US EPA, 2000; Wegener, 1994, etc). It is similar to MEPLAN (ME&P, 1995) in its representation of spatial interaction between urban activities by using the input-output modeling framework. The main feature that distinguishes TRANUS from MEPLAN is the concept of 'scaled utilities' in its spatial allocation logit model. Since TRANUS is a general model framework, a certain design must be specified for each application. In our study, we applied TRANUS model to Sapporo Metropolitan area, which is located in the northern main island of Japan. It is markedly monocentric with about two millions population. Public transportations are well provided; including the commuter railway lines (JR lines) and three subway lines. The zoning system is the one really used in the transportation planning of Sapporo, i.e., 73 zones. The following paragraph briefly describes TRANUS Sapporo. Reader is recommended to consult De la Barra (1989) for more detail about the TRANUS framework.

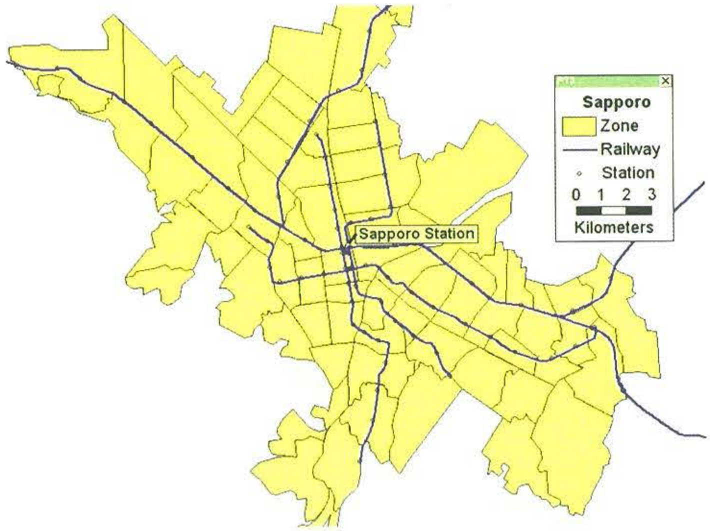

Figure 2 Study Area of TRANUS Sapporo

There are three main sub-models in TRANUS, i.e., activity (land-use) model, interface model, and transportation model. Firstly, the activity model (or so-called land-use model) operates with three groups of sector namely resident, business (employment), and land. In TRANUS Sapporo, the resident is represented by household. We have only one sector of household in our model because of the fact that social segregation is not strong in the Japanese society. It is, however, worth noting that most of the applications of TRANUS or MEPLAN model have several classes of household by income level. The business is represented by three workers; namely primary, secondary, and tertiary sectors; which were also used in the real transportation planning of Sapporo. The primary and secondary sectors are exogenous while the tertiary sector is endogenous. The land is represented by two types of urban land; namely residential (Res land) and commercial land (Com Land), whose growth are constrained by the total developable land (Dev Land). The relationships among these economic sectors are represented by 'Social Accounting Matrix', see Table 1. In this table, the relationships among sectors are either fixed or elastic. The fixed relationship is represented by the fixed coefficient (f), which is the fixed consumption of producing sectors by consuming sectors. This is similar to the technical coefficient in the input-output modeling. Specifically, workers (of all three employment sectors) consumption of household is represented by the average number of worker per one household (f1). Similarly, household consumption of service of tertiary sector is represented by ratio of the number of tertiary sector by the number of household (f2). The elastic relationship is represented by the elastic coefficient, which is price-elastic (e). That is, e1 and e2 represent the price-elastic consumption of land by household and tertiary sectors.

Secondly, the interface model links the land-use (activity) model and the transportation model, which is shown by the small matrix just below the large matrix in Table 1. That is, c1 and c2 represent conversion of interzonal/sectoral flow from the activity model (in household or worker units) into travel flow for the transportation model, by trip categories: work and private trips. The work trip is derived by workers in the household going to work while the private trip is derived by tertiary workers providing service to residents (or household). Thirdly, the transportation model calculates mode split and assignment to the transportation network. The changes of transportation during 1980 to 1995 are the major development projects such as new subway, highway, railway stations, etc. Moreover, there is an incremental model, which keeps the model within the control total. The economic growth is modeled by a fixed rate of growth in exogenous sectors.

Table 1 Social Accounting Matrix of TRANUS Sapporo

Producing / *Consuming*	Primary	Secondary	Tertiary	Household	Res Land	Com Land	Dev Land
Primary				f 1			
Secondary				f 1			
Tertiary				f 1		e1	
Household			f 2		e2		
Res Land							1
Com Land							1

Work				c1
Private			c2	

The model takes 1980 as base year and runs with quasi-dynamic structure to 1995 as shown in Figure 2. The model was calibrated at the base year, in which the model residual has been compensated. Figure 4 illustrates that, after the residual compensation, the base year forecast of household in 1980 is exactly equal to the real number. However, only base year calibration is not relevant to model the changes of urban elements in the quasi-dynamic structure. Therefore, an interval calibration is conducted for the period of 1980 to 1985. The result of the interval calibration is shown in Figure 5 with the satisfactory result (R^2 of 0.6161). For validation, the model is to forecast household distribution in 1995.

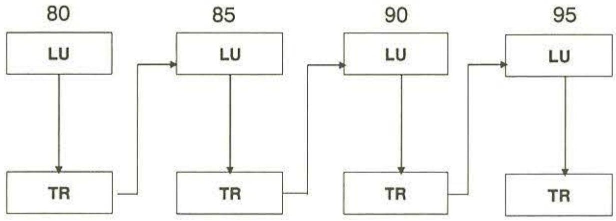

Figure 3 Quasi-Dynamic Structure

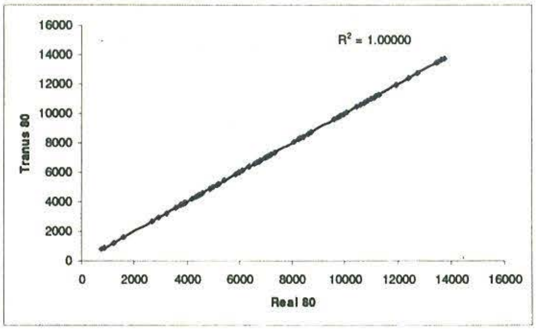

Figure 4 Base Year Calibration Result

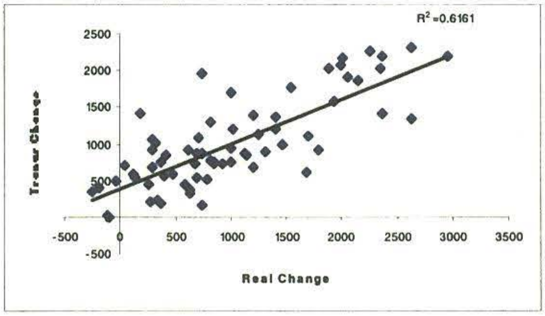

Figure 5 Interval Calibration Result

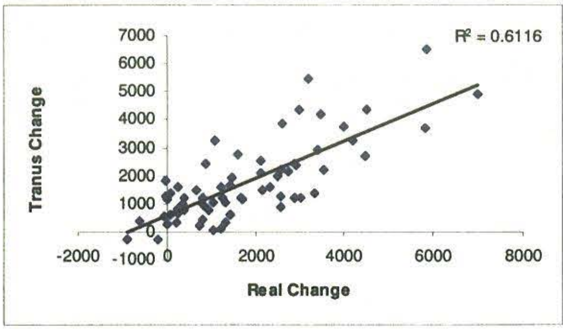

Figure 6 Validation Forecast

The comparison of change in household from 1985 to 1995 with the change obtained from the model is shown in Figure 6. It can be seen again that the model can represent the change satisfactorily with R^2 value of 0.6116. Therefore, the satisfactorily calibrated and validated model can be used for further analysis.

3. PRIMARY CAUSE OF ERRORS IN TRAVEL DEMAND FORECAST

The most common method to forecast travel demand in a regional or urban area is to apply the conventional four-step transportation model, which is consisted of trip generation, trip distribution, mode choice, and route assignment models, as shown in Figure 7.

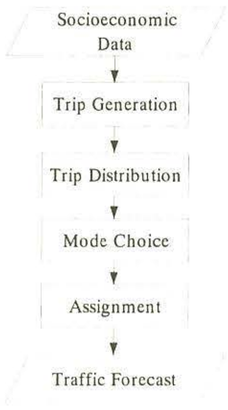

Figure 7 Conventional Forecasting Approach

The travel demand model is based on the concept that the travel is derived from the need to participate in many daily activities which are spatially separated such as work, school, shopping, entertainment, etc. It uses the zonal socioeconomic or land-use data as the main input, which are the number of population, household, employment, etc. As a consequence, the process by which socioeconomic data are estimated in the base year and forecast for future years has a significant role to the accuracy and reliability of the final forecast of travel demand. In the other word, a poor socioeconomic input will never produce an accurate forecast of travel demand in the final stage. Therefore, it is necessary to pay more attention to produce an accurate socioeconomic input to the travel demand model. The focus is now to produce such an accurate input, which is conventionally produced based on the expert's opinion or a basic forecasting model. Another solution is to introduce the land-use modeling to forecast such data by taking into account the interaction of land-use and transportation. This will be discussed in the next sections with empirical results.

4. NECESSARY TO CONSIDER LAND-USE/TRANSPORT INTERACTION

It is well known that there is a close relationship between transportation and land-use. Transportation affects land use and land use affects transportation. For long, this statement has been made by planners, economists, engineers, legislators, and politicians, perhaps for centuries. Since middle of the twentieth century, attempts have been made to quantify this relationship with respect to specific effects that changes in transportation might have on residential and/or commercial location, and vice versa. The traditional transportation modeling approach, as discussed previously, represents the response of transportation to the condition of land-use; but the response of land-use to the change in transportation is however not represented. In the other words, land-use is assumed to have no response to change in transportation condition. In this section, a case study is presented to quantify the effect of transportation change to land use by using TRANUS Sapporo model. The transportation change is represented by the new section of subway line, namely Toho Line North Section which is opened in 1990, see Figure 8.

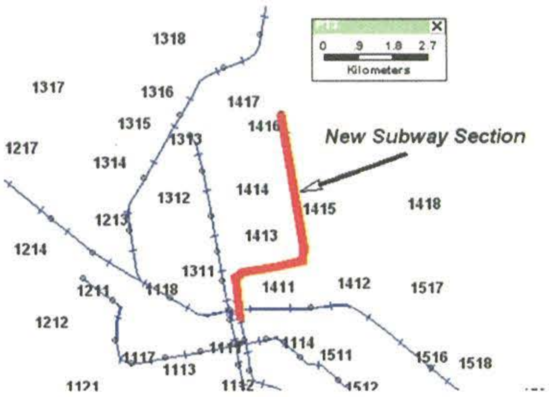

Figure 8 New Subway Section

Land-use effect due to transportation change (introduced by the opening of a new subway section) is observed by with-without analysis. We compare the distributions of household in 1995 of the two cases; and the difference is shown in Figure 9. The yellow bar shows that zones are gaining resident while the red bar shows that zones are losing residents.

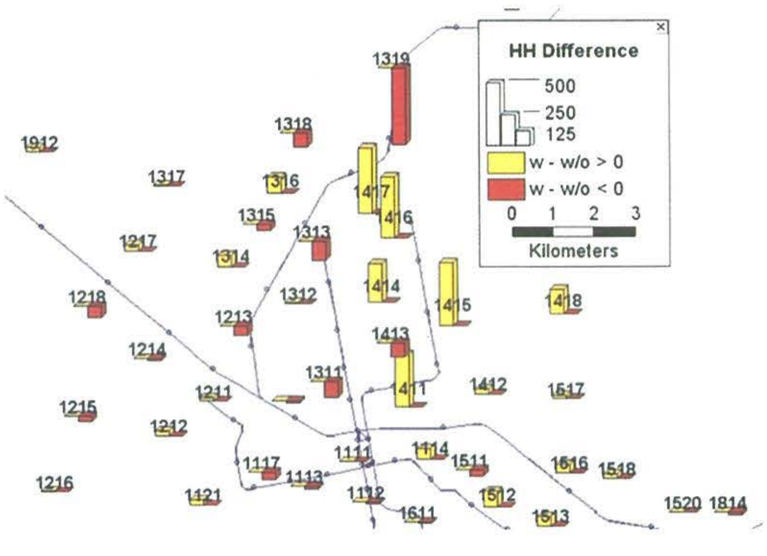

Figure 9 Difference of With and Without Case

Clearly, the difference is large in the area along the new subway as expected. This means that the impact of transportation to land-use is large especially in the vicinity of new transportation development. Specifically, it is observed that zones are gaining more household after the new subway is opened; i.e., the number of household in with-case are larger than without-case. This is because the improved accessibility introduced by subway. However, it is interesting that some zones are losing their household, e.g., zone 1319 and 1413. The with-case of zone 1319 and 1413 has smaller numbers of household than the without-case. People in zone 1319, which were served mainly by inconvenient JR railway, are moving into inner area where subway service is better. Similarly, people that previously located in zone 1413 are now moving out of the city along the subway, i.e., suburbanization. Therefore, it is shown by empirical results that land-use has strongly response to the change in transportation. The hypothesis is true that impact of transportation to land-use is so large that the land-use/transportation interaction must not be neglected in the modeling and analysis, especially travel demand forecasting. As a consequence, a considerable benefit could be expected by introducing land-use model into the travel demand forecasting, and this is discussed next.

5. MORE ACCURATE SOCIOECONOMIC DATA BY LAND-USE MODEL

This section presents an improvement of socioeconomic forecast by introducing land-use model, again with empirical result of the TRANUS Sapporo. We compare the real 1995 socioeconomic forecast used in the person trip analysis of Sapporo (PT forecast) with the forecast that obtained from TRANUS Sapporo model. The PT forecast (Hokkaido Development Bureau, 1985, 1995) was made in the traditional way, which was based mainly on the experience and insight of the planning experts. Although the information about the future development projects was considered, there was no specific method of making the forecast. The PT forecast is the input to the transportation planning of Sapporo.

The two forecasts are in different units, i.e., the PT forecast are in population while the TRANUS forecasts are in household. Essentially, a fair conversion scheme is required for a meaningful comparison. The conversion is based on the average household size (the number of members in a household) in 1995 by zone, shown in Figure 10. The household size is relatively small in the central area but it is larger in the outer areas. In one direction, the population-equivalent TRANUS forecast is obtained by multiplying the number of household by the average household size. Similarly, the household-equivalent PT forecast is obtained by dividing the population by the average household size.

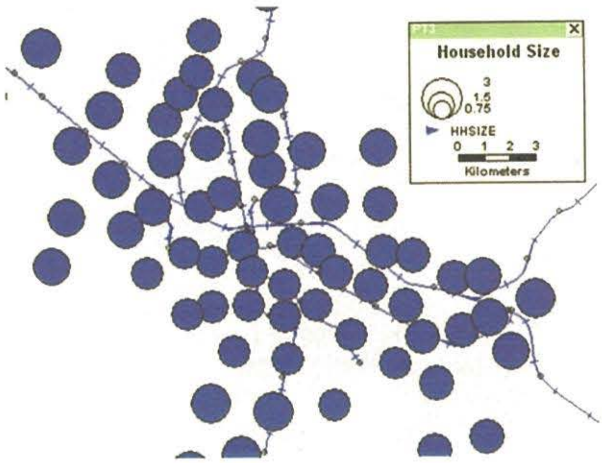

Figure 10 Conversion by the Average Household Size

We compared the forecasts in both units, i.e., the household-based comparison and population-based comparison, which are shown in Figure 11 a and b respectively. The first bar shows the real number of resident in 1995; the second one show the PT forecast; the third one show the TRANUS forecast for with-case; and the last one show the TRANUS forecast for without-case. Both household-based and population based comparison exhibit the results in a similar way. That is, in the area where the difference between with- and without-case are large, the PT forecast are underestimated while the TRANUS forecast are closer to the real value. Moreover it is observed that the PT and TRANUS forecasts are more or less similar for the other areas where the differences of with and without case are not pronounced. Let us consider zone 1415 where the difference of with and without is obviously large. The PT forecast is underestimated while the TRANUS forecast is more precise. On the other hand, in zone 1416 and 1417, the PT forecasts are overestimated while the TRANUS forecasts are more precise. In overall, the TRANUS forecast, either in population or household, are more accurate than the PT forecast in the vicinity of new transportation project. Based on the empirical results, it is evident now that the PT forecast, which is the input to transportation model, is not very accurate. We claim that the model would never produce accurate forecast of travel demand unless the input is accurate. The accuracy of this input could be improved by using the land-use/transportation model, which fully incorporates land-use/transport interaction. The more accurate model input, the more accurate output could be expected.

It is worth to mention that although the evaluation of travel demand forecasts by the two methods is important, it is beyond the scope of the present paper. This is because the accurate forecast of travel demand requires very detailed transportation model but the present version of TRANUS Sapporo model have rather coarse transportation detail, which is judged relevant to make socioeconomic forecast.

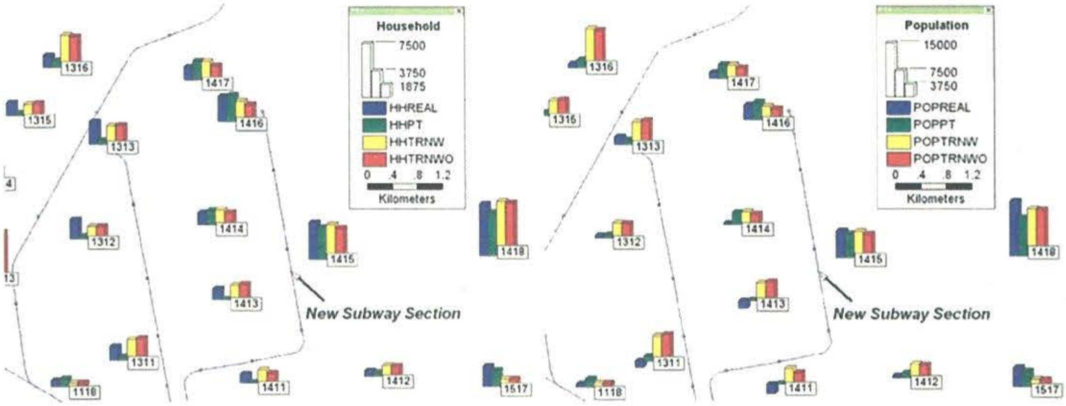

Figure 11 Residents Forecast: a) Household based, b) Population based

6. CONCLUDING REMARKS

This paper has presented, by empirical result, the improvement of the travel demand forecasting practice by using land-use model to make a more accurate socioeconomic input to the travel demand model. The more accurate the input is, the more accurate and reliable travel demand could be expected. This would benefit the modelers in many ways; for example, the metropolitan planning organization in USA will pass the federal requirements of air quality and environmental standards, etc. Moreover, we also presented that transportation effect to land-use is so large that land use must be seriously considered in the transportation analysis. This inevitably becomes a strong evidence to promote the use of integrated land-use /transportation models. The case study presented is the application of only TRANUS land-use/transportation model, which is an aggregated quasi-dynamic urban model. The similar application of the other state-of-the-art urban models (including those detailed microsimulation urban models) will help to support the results obtained. Furthermore, it is worth to mention that the discussion and analysis in this paper is shown with the empirical analysis, which does not exist previously due to many reasons such as data availability, technical readiness, etc. The study is one application of the Sapporo Test Bed, which is a general tool to implement and test urban models (Vichiensan, 2003); a similar analysis to this paper with other land-use model could be done easily.

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