ABSTRACT

This paper presents a study of land use transportation interaction in the developing countries context. Several issues regarding the development of land use model in developing metropolis is discussed and a case study of Bangkok is presented. The present situation of urban and transport development is described, showing that land use interaction is not explicitly considered in the transportation analysis. Empirical evidence from the railway projects shows that interaction of land use and transportation interaction is quite strong and must not be ignored. To analyze land use and transportation interaction, an effective tool is required. Among the existing urban models, TRANUS is selected as a pilot system for Bangkok for several reasons. The design and calibration of Bangkok model are described. Scenario analyses provide insight how land use is incorporated in the comprehensive urban transportation analysis scheme. Policies such as road pricing or TOD are effective countermeasures to compact the city and relieve traffic congestion. Lessons learned from the present system gave an idea of to develop an integrated land-use transport and the environment for Bangkok.

Keywords
Developing Country, Land Use, Transportation, TRANUS, Bangkok

INTRODUCTION

That transportation and land use has closed relationship, i.e., transportation affects land use and land use affects transportation, has long been recognized by planners, economists, engineers, legislators, and politicians, perhaps for centuries. The traditional transportation modeling approach represents response of transportation to land use condition; but response of land-use to change in transportation is, however, not represented. In the other words, land use or land development is assumed to have no response to change in transportation condition. In the past few years, mathematical approach has been employed such that there are several operational urban models available. However, these large-scale models are data-hungry and require extensive effort in the model development. Unfortunately, it is characteristic of developing countries that such data required by urban model, especially land use and land price data, is neither readily available nor complete.
What is Difficult in Developing Countries

Most of the developing countries are experiencing rapid growth of urban area, uncontrollable suburbanization, uncoordinated land use, inefficient infrastructure development. These generate large amount of travel demand, give rise to the number of vehicles, and eventually result in traffic congestion. Most of the time, a solution to traffic congestion problem is to build more road, but this inversely induces more traffic; so the problem is not solved. On the contrary, land use planning and control are keys to the success. Planned and coordinated land use together with planned infrastructure will be necessary. From the planning viewpoint, the economic activities generated by transportation must be accurately estimated. Land price must be forecasted by taking into account transportation condition change. This may be achieved by using a quantitative urban model.

In the modeling context, the existing urban models are built upon the requirements of model developers, which do not always meet limitations in the developing countries. These include availability and reliability of the data. Input to the model including data and human resources must be carefully developed. In some cases, there are debates that land use (or socioeconomic pattern) is too abstract to be quantified and recognized in transport analysis. Such misunderstanding may be eliminated by demonstrating a feasible land use methodology. Simpler model might be more attractive and useful for developing countries. In many cases, a number of simplified models for transportation planning have been proposed and implemented.

However, there might be situation that requires complicated modeling technique; in this case analyst should look for an appropriate method to the problem. Recently discrete choice models for location analysis have obtained more interest from researchers, [1] and [2]. Similarly, efficient techniques to prepare data for urban model may also be good tool for modelers in developing countries, [3]. There are some attempts in developing countries. To name a few, in Metro Manila, a microsimulation model of household location is proposed to produce an artificial set of urban locators in the land use model [4]. In Johannesburg, a simplified land use model is applied to produce a reliable set of input to transportation demand model, which previously used a constant set of land use [5].

In Bangkok, the government has paid attention to transportation modeling over the past ten years. It is largely built upon the conventional 4-step approach, [6]. Several versions of the travel demand models have been developed, ranging from macroscopic to microscopic levels. Extensive efforts are paid for model maintenance to update the database, [7] and [8]. The latest version of Bangkok transport model is built upon Citilabs’ proprietary software CUBE. Its Bangkok application is called e-BUM, which stands for ‘extended Bangkok Urban Model’, though it only considers transport. 625 zones are used with extensive transport network. However, its land use assumption is a major drawback of the present system. In words, the future land use is considered exogenous or given in the transportation analysis. Therefore, the evaluation of transport alternatives is conducted by using the same set of future land use. It means effect of transportation to land use is ignored, for example, accessibility improvement, increase of development potential, increase in land value eventually.

Therefore, it must not be wrong to conclude that an ideal architecture of land use/transport model for developing countries must be based on simple framework, which requires low-cost data and less-effort in the model development. Feasibility of the implementation should also be kept in mind. Since the survey data in developing countries is not always very accurate. In addition, the uncertainty inherent in the dataset must be explored and controlled; otherwise error will be magnified so that the model results are reliable [9], [10]. Lastly, graphical user interface must be emphasized so that the analysis approach and its result can be translated and accepted by the stakeholders, e.g., by employing efficient GIS linkage.
TRANSPORTATION AND URBAN DEVELOPMENT IN BANGKOK

Bangkok Metropolitan Region

Bangkok Metropolitan Region (BMR) area comprises of Bangkok Metropolitan Area (BMA) and its five adjacent provinces. BMR covers 7,758 sq km. The total population of BMR in 2004 was 9,636,541, or 15.5% of the total population of Thailand. The central area of BMR is called Bangkok Metropolitan Area, or shortly BMA. It covers 1,568.7 sq km and is centered to almost all urban activities: business district, high to medium density residential areas, as well as industrial area. In 2005, BMA produced a GDP of about USD 220 billion, which accounts for about 43% of the country's GDP. Since 1960 BMA has been undergoing rapid urbanization and industrialization. The increase in population is due to the development of infrastructures such as road networks as well as real estates. From 1987 to 2000, the number of population has been decreasing in the inner area, but increasing in the middle area. That is, the population density in the inner area decreased from 15.27 to 11.09 thousand/sq km (that is 3.25 to 2.36 million). The outer area has increase in the population density from 0.77 to 1.28 thousand/sq km (which is 0.67 to 1.12 million). As of April 2006, BMA is home to 5,672,721 inhabitants, resulting in a density of 3,616 persons/sq km.

Major of travels in Bangkok are made on road. In 2005, the share of private mode is 53% while that of public mode is only 44%. Road and expressway network have played important roles in accommodating the travel demand because they provide convenient service to the destinations. Meanwhile, the public transport service is inadequate. It does not comprehensively cover the whole urban area. People living in sub-urban areas then prefer traveling by private car than using bus. This produces large amount of traffic volume on road and causes traffic congestion. In 2000, there were 4,076 kilometers of road length, which accounts to 58.45 square kilometers. The present expressway length is 175.9 kilometers. Expressways are still being constructed for further 82.3 kilometers, and planned to build 64.1 kilometers after 2009.

In terms of public transport, bus is the main mode. Presently, 404 bus routes are available. In addition, some sub-urban people are commuting to the central Bangkok by using sub-urban railway; a service provided by State Railway of Thailand (SRT). Recently, urban rail transit or metro systems were introduced. In December 1999, an elevated 'Skytrain' metro system (officially called BTS, stands for Bangkok Transit System) was opened. Currently, BTS has two routes, Sukhumvit Line (Green 1) and Silom Line (Green 2). Approximately, BTS carries over 400,000 passengers per day. Five years after BTS opened, a new MRT subway system was opened in July 2004. It connects SRT’s northern long-distance train station, Bang Sue, to its central station, Hua Lamphong. It connects to BTS system at three transfer stations: Mo Chit, Asoke, and Sala Daeng. Although the expressway network together with BTS, MRT, and SRT railway lines have eased the problem a little, much more needs to be done for the betterment of the city.

Bangkok City Planning 2006: Land Use Regulation

Previous studies, [11], indicated that traffic problems in Bangkok were originated from inefficient master plan, inefficient planning and design standards, ineffective land-use control, unstructured hierarchy of road network, as well as inefficient public transport system. In a bigger picture, Thailand has become automobile-dependent during the past transportation plans and policies. Road-based transports had obtained top priority, taking almost all of the budgets available for transport infrastructure development. However, less attention is given to land use regulation or land use control to structure the city in accordance with the master plan. The first revision of Bangkok City Planning, or so-called Comprehensive Plan, was devised in 1999. Recently, the plan was revised by adding changes in the circumstances since the first revision. Now, the second revision is now active; so called the Ministerial Regulation on Bangkok Comprehensive Plan BE. 2549, [12]. In the plan, land use plan is described. Comparing with the previous plan, land designation were changed in some parts of the city; reflecting increased development. Many of the changes are due to transportation development.
Transportation demand is forecasted from 2002 to the next 20 years. Congestion in the inner area, i.e., the area surrounded by Ratchadapisek middle ring road, is reportedly becoming more severe. The average speed reduces from 18 km/hr in 2002 to 14 km/hr in 2009, and 12 km/hr in 2022. Although roads are becoming more congested, people still prefer traveling by private cars. Share of public transport reduces from 45% in 2002 to 40% in 2009, and 38% in 2022. It is, therefore obvious that Bangkok needs a proper set of countermeasures to alleviate the traffic congestion problems. Land use regulation and the related measures must be carefully considered and applied. The measure may be to provide transport infrastructure such as urban rail transit. In this case, understanding its impact to urban development will provide good information for the other policy measures. This is discussed next.

**Development Impact of Urban Rail Transit**

The BTS elevated railway has been servicing Bangkok travelers for seven years while the MRT subway blue line has recently started. Figure 1 shows the central area of Bangkok consisting of three railway lines: MRT Blue, BTS Green 1, and BTS Green 2. Interest is given to the five adjacent areas along the railway lines. Areas 1 to 4 are along the MRT line while area 5 is along the BTS line.

Let us first consider MRT. MRT runs through the eastern side of Bangkok, passing through the central business district and connecting to the residential area in the north. After the subway blue line service started, there were significant developments in the influence areas. They are said to gain benefits due to accessibility improvement. The land use designation of these areas as appeared in the previous and the new land use plan are compared in Table 1. Roughly no major change between the two plans is noticed because most of the MRT sections are in the CBD. In these areas, the area within 500-meter distance from MRT center-line is permitted for buildings with floorspace greater than 10,000 sq m. Farther away, such big buildings are not allowed. A closer look allows seeing that areas 1 to 3 are changed but only in sub-category. Only the area 4 is upgraded from medium-density to commercial and high density residential. Therefore, in this area, development such as office building, shopping area, and condominium will continue.

In terms of land value, the officially assessed land prices, which is published every 4 years by the Treasury Department, are not changed much as well. Although the assessed land price is not exactly equal to the real market price, it indicates to some extent the trend of land value. The presently published land value does not reflect the fact that these areas have very high potential for development. It can be expected that floor rent will be raised up, especially in the potential areas like Ratchadapisek or Ladprao on the eastern side of MRT. Furthermore, it is obvious that there is mismatch between land use designation and land value assessment. The areas with high development potential are under-assessed. As a consequence, land buyers will largely gain benefits due to the low price. In addition, when the real value is widely recognized by the public, there will be no way to capture the increase in land value and return the profits back to the railway developer.

Next let consider BTS. Having operated over 7 years, there were significant changes in the adjacent area along BTS. The area along the 5.5-km eastern section of BTS, from Asoke station to On-nut station, is observed. The area along this section was previously outer area having traffic congestion problem, but has undergone rapid development as can be seen by the increased number of office building, high-rise condominium, large retail store, shopping complex, etc. Traffic condition along BTS is being improved as people are changing mode to travel on the elevated BTS instead of driving private car in the congested traffic under the BTS structure.
(a) Influence Area of Subway Sections

(b) Impact of Railway to Land Price

Figure 1  Impact of Railway: (a) Influence Area, (b) Land Price Change
Table 1 Land Price and Land Regulation along the Subway BLUE Line

<table>
<thead>
<tr>
<th>Influence Area</th>
<th>Officially Assessed Land Price (Baht/Wah²)*</th>
<th>Land Use Regulation 1999</th>
<th>Land Use Regulation 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rama IV</td>
<td>140,000 - 380,000</td>
<td>170,000 - 380,000</td>
<td>Commercial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial</td>
</tr>
<tr>
<td>2. Asoke</td>
<td>130,000 - 260,000</td>
<td>150,000 - 260,000</td>
<td>High Density Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High Density Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Commercial</td>
</tr>
<tr>
<td>3. Ratchadapisek</td>
<td>60,000 - 250,000</td>
<td>100,000 - 250,000</td>
<td>High Density Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium Density Residential</td>
</tr>
<tr>
<td>4. Ladprao</td>
<td>60,000 - 130,000</td>
<td>85,000 - 120,000</td>
<td>Medium Density Residential</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High Density Residential</td>
</tr>
</tbody>
</table>

*Thai Measurement Unit: 1 Wah = 2 meter; 1 square Wah = 4 square meter

This study observed the change of the officially assessed land prices in the area within 500 meters from the BTS center line. The change is observed between 1992 and 2006. In total 1,500 samples of historic land prices are obtained from the Treasury Department. A contour of the difference between 1992 and 2006 is plotted shown in Figure 1b. Each interval represents 10,000-Baht change in land price between the two points in time. The narrow gap contour shows abrupt change in land price during 14 years, before and after the BTS service. Clearly, land prices are remarkably increased around the BTS stations. The impact is especially pronounced around Asoke station, which is the transfer station between BTS and MRT. In the past, the intersection beneath Asoke station was in severe traffic congestion condition, so firms were looking for less-congested place to locate. But after the BTS service as well as the MRT construction started, office buildings were returning and continuously increasing. This is solely benefits of the mass transit. Likewise, the areas around BTS On-nut end terminal were largely developed due to improved accessibility provided by feeder bus, taxi, or park-and-ride. In the similar way, land value of the surrounding area of Phrompong station has been increased by the effect of a large shopping centre as well as the green public park. This is also similar to the area around Ekamai station, which is connected to a long-distance bus terminal.

In conclusion, BTS impact study showed that the station surrounding areas have very large potential for development whereas the farther area gains benefit by improved accessibility. Similar development situation to BTS will happen with MRT, but may take longer time so that the effects can be seen. This is because more than half of the MRT sections are not in the high density area. In any circumstances, land use regulation and land value assessment will play important roles in leading the development direction, so must be seriously considered. Nevertheless, the nature of land market and its relationship with the other urban subsystems are still very complicated. The only way to explore it is to make a quantitative analysis with mathematical modeling, and will be discussed next.

**TRANUS MODEL OF BANGKOK**

Urban modelers around the world have made over thirty operational models. Some are being used in many applications, as described in the reports such as [13] and [14]. These models are tailored to meet the requirements and objectives of the application as well as to meet the local characteristics of the case study. Recently, a number of new models are proposed based on the microsimulation framework. However, these models are sacrificed by the inefficiency in computation resource consumption either in terms of data or time. The aggregate models such as MEPLAN or METROPILUS, though being
built upon different theoretical framework, are still the success stories and still in-use nowadays. For example, MEPLAN has been applied in many European cases. Sacramento MEPLAN application has also been research exercises for many years, [15]. Similarly, TRANUS has also been applied in many places, including Sacramento [16] and Sapporo [17]. Largely in the United States, several applications of METROPILUS are still active in many metros.

In Thailand, several attempts have been made to develop an integrated land-use transportation model. In 1986, BALUTAS was developed as a simplified land use model to represent the particular land market in Bangkok, [18]. Its computing efficiency was judged very satisfactory with respect to the computer technology at that time. In 1992, a Bangkok version of RURBAN was developed with graphic user interface under Windows 3.1 environment, [19]. However, the model was no longer updated. Recently, there was an attempt to model land use in several Asian Cities, though not including Bangkok, by using an European land use model called MARS, [20]. It concluded that direct transfer of the model to local application in Asian cities was not possible because many modifications are required at the calibration stage such that it is able to represent local characteristics. Therefore, the present study is another attempt to develop an integrated land-use transport model for Bangkok Metropolitan. In this paper, TRANUS is employed in the first phase of the study, which has objective to examine the present modeling capability in terms of data availability with respect to functional requirements. TRANUS is flexible enough to meet the study objectives. The study also determines the points to focus in the next-phase study. Such information will be feed into the design of the mode in the later phase. It is, however, worth mentioning that TRANUS is appropriate because the software has graphic interface with full documentation.

Framework of TRANUS

Developed by De la Barra [21], TRANUS is one of the existing operational models that have been used in many real urban and regional applications. TRANUS is similar to MEPLAN in the way to represent spatial interaction among urban activities by using input-output model framework. The main feature that distinguishes TRANUS from MEPLAN is the concept of ‘scaled utilities’ in TRANUS’s logit model to allocate activities to different zones. Since TRANUS is a general model framework, a certain design must be specified for Bangkok application and will be described next.

Design of Bangkok Model

In one time period, there are three modules to model land-use and transportation interaction, 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 sectors namely resident, business (employment), and land sectors. In TRANUS Bangkok, residents are represented by households. There is only one sector of household in our model due to the fact that social segregation is not obvious in the society. It is, however, worth noting that most of the applications of TRANUS or MEPLAN models have several classes of household, often classified by income class. Business is represented by three groups of employment namely primary, secondary, and tertiary employment sectors. This is the same employment classification as in e-BUM, the official Bangkok transport model [8]. The distribution of the primary and secondary employment sectors are exogenous (or given) while the tertiary sector is endogenous (or to be determined by the model). Land sector is represented by one sector called Land. Relationships among these economic sectors are represented as the ‘Social Accounting Matrix’ as shown in Figure 2. Fixed relationship between sectors 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 an input-output model. To be specific, workers (of all three employment sectors) consumption of household is represented by the average number of worker per one household. Similarly, household consumption of service of tertiary sector is represented by ratio of the number of tertiary sector by the number of household. The elastic relationship is represented by the elastic coefficient, which is price-elastic ($e$), representing price-elastic consumption of land by household and tertiary sectors. The equilibrium in land market is sought by iterating the model until convergence in price and production each sector.
Secondly, the interface module links land-use (activity) and transportation modules. That is, notation $i$ in Figure 2 represents conversion of interzonal/sectoral flow from the activity model (in household or worker units) into travel flow for transportation model, by trip categories: work and private trips. Work trips are derived by working members of a household commuting to work while private trips is derived by tertiary workers providing service to households. Thirdly, the transportation module carries out mode split and traffic assignment of the traditional 4-step approach. Two modes of travel are defined: private and public. Private-mode travels are made by private cars while public mode is consisted of railway transit, taxi, and non-motorized transport. Although bus is presently a majority mode of public transport in Bangkok, it is not explicitly represented yet. But rather, bus is implicitly included in the present system as part of taxi. After the transportation model converged, the interzonal transport cost is calculated, which will affect location decision of sectors in the next time period. Then, the system moves forward to the next time period by the incremental module that specifies growth of economic sectors. The growth is represented as change in the exogenous sectors. In this application, base year is 2005; each time step is 5 years; and target year is 2025. Such temporal structure is so-called quasi-dynamic, i.e., land use affect transportation rapidly in the same time period where transportation affects land use in the next time period. However, this concept contradicts the assumptions used in Bangkok transport model as discussed earlier.

*Adapted from [15]  

Figure 2 Social Accounting Matrix and Transport Model Interface
Data and Calibration

This section shortly describes about the data used to develop TRANUS Bangkok. The study area covers the area of Bangkok Metropolitan Administrative (called BMA), which is a part of Bangkok Metropolitan Region (BMR). The total area of BMA is 1,568.737 sq. km covering 50 jurisdiction districts. Zones are comprised of 50 internal zones, following 50 BMA districts, and 8 external zones. These external zones are used to represent the traffic in/out the study area. It is, however, worthwhile to mention that each TRANUS zone consists of several small zones used in the e-BUM model, as shown in Figure 3a.

In 2005, BMA has 6,634,326 population; 1,841,841 households; 60,317 primary employments; 1,169,503 secondary employments; and 2,141,537 tertiary employments. The zonal numbers of economic sectors are specified to be the same as the socioeconomic data of e-BUM. Land use data is the land use statistics used in the Bangkok Metropolitan Planning Study [12]. Land price is obtained from the land price statistics published by Treasury Department, also used in [12].

The multi-modal transportation network consists of 17 link types. 10 highway link types include one-way road, dual carriage way, flyover, bus-only link, minor road, major road, expressway, on-ramp, off-ramp, and centroid connector. Non-motorized transports such as walk and cycling to traverse are allowed on most links except the expressway-related links. 5 railway links include subway/urban railway link (operated by BTS and MRT), sub-urban railway link (operated by SRT), railway access, railway interchange, and centroid connectors to the railway. In the later years, two special highway link types are added in the road pricing scenario: pricing links on major and minor roads. Some types of link such as highway links are capacity restraint while but some types such as transit or walk links are not, as shown by $c$ and $n$ in Figure 2 respectively. To illustrate, Figure 3b shows the transportation network of TRANUS Bangkok in 2025, the horizon year. The new airport named Suvarnabhumi is located in the south-eastern area; while the old airport named Donmuang is located in the north. In terms of cost parameters, value of time is 0.95 Baht per minute. Vehicle operating cost for private car is 0.936 Baht per kilometer. Toll on expressway is collected at a constant basis, i.e., 40 Baht collected on the on-ramp link. Taxi fare is starting from 35 Baht and adds 1 Baht per kilometer. Fare on MRT and BTS is on a distance-basis; boarding fare is 10 Baht and distance fare is 1 Baht per kilometer. In the calibration, TRANUS is adjusted and fine-tuned so that the base year results are similar to the base year input/output of e-BUM. Land use is calibrated by the internal calibrating module of TRANUS while transport is calibrated by checking speed and traffic volume on major roads and screenlines.
Figure 3 TRANUS Bangkok: (a) Zone System, (b) Transportation Network
SCENARIO ANALYSIS

Base Scenario

In base scenario, the whole study area grows into the future with the present transport network, which consists of the existing expressway network and the existing urban and sub-urban railway lines (BTS, MRT, and SRT). Growth in each five-year is specified by a change of 13.5% reduction of primary employment, 1.3% reduction of secondary employment, 10.4% increase of tertiary employment, and 7.5% increase of household. This framework, again, follows that of e-BUM.

Full Expressway and Railway Network

It is realized that the existing BTS and MRT provides only 42-kilometer core network of mass rapid transit. However, this is inadequate to improve traffic condition in Bangkok. The government proposed to construct a full network that is consisted of subway, sub-urban railway, and expressway, based on the following policy. Network is consistent with the regional and urban plan, especially land use plan. Fare and toll are reasonable and acceptable. Implementation is through the public and private partnership in order to reduce large amount of investment by the government. As a result, a 291-kilometer extension of the MRT network is planned, as shown in Figure 4. The full extension is expected to finish in the near future. In this study, the full network is present in TRANUS from 2010, which will then have effect to land use from 2015.

*Adapted from Office of Transport and Traffic Policy and Planning

Figure 4 Full Railway Network
Road Pricing

Presently, traffic congestion in the inner area of Bangkok is becoming more severe, as indicated by the average speed of less than 15 km/hr. The Bangkok city planning study found that with the full transit network, public transport share will be only 40% in the future, which implies that the present transport measure is inadequate to alleviate the problem. Reducing car dependency in certain areas of Bangkok is a new idea to shift mode choice from private to public. This is also to reduce trip length and amount car use, which will improve the traffic condition at the end. In this scenario, 30 Baht toll is charged when private cars cross the cordon line in the in-bound direction. The cordon lines are Chaopraya river and the imaginary circumference of the inner area, as shown in Figure 5a. The River screenline is on the left and the imaginary screenline is on the right. Toll links are colored in blue.

Transit Oriented Development (TOD)

The analysis of transit impact to land development presented earlier has shown that the area along the transit line has high potential for development due to the improved accessibility. TOD scheme aims to increase residential and commercial activities around the station in order to maximize the use of transit access and non-motorized transport. In TRANUS, with the full network as in the previous scenario, some areas are promoted for intensive residential and commercial development by increasing the available developable land. This scenario represents an urban structure with sub-centers. In this case, five sub-centers are represented: Bangsue, Bangkapi, Bangna, Ratburana, and Thapra, as shown in Figure 5b. These areas have good transit accessibility because they are either interchange station or terminal stations.
Figure 6  Transit Oriented Development

New Airport City

The new Bangkok International Airport, named Suvarnabhumi Airport, is located 20 kilometers east of Bangkok. The airport full service starts in September 2006. At the initial stage, it is capable of handling 45 million passengers and 3 million tons of cargo per year. In terms of ground transportation there are presently 5 highway routes to access the airport. In the near future, the airport access railway, operated by SRT, will start its service in 2009. This then will make the area more accessible. So far, land speculation can be observed in the airport vicinity. Previously there were only a few industrial factories and warehouses, but presently a lot of real estate firms are present and developing high-class residential village, industrial estates, office buildings, etc. The government proposed to develop the airport area for industrial, commercial, and residential uses, covering 521.8 sq.km. These area cover BMA and its surrounding cities. BMA’s two districts are Ladkrabang and Prawet. Total population in the new city is expected to be 462,100. In the model, the attraction parameters are adjusted so that zone 1014 (Ladkrabang) and 1034 (Prawet) is more attractive to locators.

Results

The results of the scenario analyses are shown by transport indicators and household distributions. The transport indicators are summarized in Table 2 while the household distributions are shown in Figure 7. In the base scenario, Bangkok has high density in the central area. Public mode share reduces to 38% in 2025 and congestion level is higher, indicated by average speed. The full network scenario does not change the urban structure, but it could relieve traffic congestion on road by shifting people to travel on public transport. For the road pricing scenario, the city has become more compact; people are moving to the inner area where public transport service is available to avoid driving car into the city. Since the average trip length is also smaller, there is less number of cars on road, resulting in the better traffic condition. In case of TOD, people are attracted to stay in the sub-center area, showing that the city is having a satellite-shape. Travel has been made easy by convenient access to railway; therefore users of public mode are larger. For the new airport case, much development is promoted in the area east of the study area. Several inner areas are losing residents to the eastern area, which is now true in reality. However, because it generates longer travel, the traffic
condition on road is not very good compared to the full network case. In conclusion, the empirical analysis with TRANUS has shown that transportation have influence to land use and vice versa. This implies that both interactions must be explicitly considered in the analysis.

Table 2 Policy Results: (a) Public Transport Mode Share (b) Congestion Level

(a) Public Transport Mode Share

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Full Transit</th>
<th>Road Pricing</th>
<th>TOD</th>
<th>New Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>44.08%</td>
<td>44.08%</td>
<td>44.08%</td>
<td>44.08%</td>
<td>44.08%</td>
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<tr>
<td>2010</td>
<td>42.47%</td>
<td>43.06%</td>
<td>44.51%</td>
<td>43.11%</td>
<td>42.98%</td>
</tr>
<tr>
<td>2015</td>
<td>40.25%</td>
<td>44.91%</td>
<td>47.32%</td>
<td>45.04%</td>
<td>44.54%</td>
</tr>
<tr>
<td>2020</td>
<td>39.65%</td>
<td>46.27%</td>
<td>47.35%</td>
<td>46.21%</td>
<td>46.41%</td>
</tr>
<tr>
<td>2025</td>
<td>38.19%</td>
<td>47.83%</td>
<td>51.79%</td>
<td>48.02%</td>
<td>47.25%</td>
</tr>
</tbody>
</table>

(b) Congestion Level : Average Speed (km/h)

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Full Transit</th>
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<td>2005</td>
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<td>20.1</td>
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<tr>
<td>2010</td>
<td>20.2</td>
<td>20.9</td>
<td>21.2</td>
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<tr>
<td>2015</td>
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<td>21.8</td>
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</tr>
<tr>
<td>2025</td>
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<td>22.1</td>
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</tr>
</tbody>
</table>

MODEL WEAKNESS

The present model, TRANUS Bangkok, of course, has weakness. At the time the model was developed, the full set of data was not available. The aggregated land use data by BMA districts are not consistent with the economic data, which is also aggregated into BMA districts. Amount of land used is not very proportional to economic activities in the zones. This has made land market model difficult. This is largely due to the fact that land use regulation was not very strong in the past. It is why only one land type is used here. The next problem is with land price. The officially assessed land value is not the real market price, but it is assumed does in the model. It is still unclear to what extent the published land price reflects the land market direction. These two points of concern had led the decision to use the large-size zone system (with 50 internal zones) in order to meet the data availability concern. With coarse zone resolution, the transport analysis will not be very accurate, e.g., certain amount of trips would all become intrazonal. In addition, modeling bus network on the coarse zones is also not very meaningful, so bus is not explicitly modeled. This make some transport-related policies are not possible such as parking, non-motorized mode, ITS, etc. In terms of travel behavior consistency, the education trip, which takes large portion of trips in Bangkok, was also not modeled.
Since the present system has sacrificed from using large-size zone system, the new model must use a finer zone system that is capable of representing travel behavior while affordable in terms of data availability. Since the land price is not the real market value, an evaluation of error in land price data must be conducted so that the uncertainty of the model results can be kept within an acceptable range. Most preferably, the zone system used in land use model must be the same as that used in e-BUM. In the other words, the next generation Bangkok model should utilize the full capability of e-BUM. This can be achieved by externally connecting the land use model with e-BUM. In this case, a proper model interface must be designed. For the model application, the same policies that are being discussed by using transport-only approach must be compared with the new approach considering both land use and transport.

CONCLUDING REMARKS

The paper is strong in twofold: exploring land use transport interaction by the empirical analysis and developing a prototype system of an integrated land use transport model. Discussion in developing country also is presented. Land use modeling is difficult due to the informative data is not always available. Certain considerations must be paid in order to achieve at a good model. Case study with Bangkok is presented. The empirical evidence from the railway project shows that interaction of land use and transportation interaction is strong and must not be neglected in the overall planning. This
calls for an effective tool to analyze land use and transportation endogenously. TRANUS model of Bangkok is then presented. The model calibration is based on the newly devised Bangkok City Plan and the official travel demand model, called e-BUM. Policy analyses also indicated that land use effect is strong and should not be considered as given or exogenous to transportation analysis. The present TRANUS Bangkok development is still on-going. A number of fine-modification is being experimented. Moreover, a number of evaluation indicators will be calculated, for example, environmental and financial indicators. Finally, lessons learned from the present model are taken into account to build a new model of integrated land use, transport and the environment, and will be presented in subsequent report.

ACKNOWLEDGEMENTS

Part of this study is supported by the Core University Program, Japan Society for the Promotion of Science.

REFERENCES


