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# INTEGRATED ZONAL IMPACT ANALYSIS SYSTEM: AN INITIAL EFFORT OF PLANNING SUPPORT SYSTEM IN DEVELOPING COUNTRIES

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**Abstract:** To manage complex urbanizations, various advanced planning techniques have been developed. A last effort is the planning supporting system (PSS). This study intends to develop Integrated Zonal Impact Analysis (IZIA) System in Bangkapi District, Bangkok, by integrating land-use databases, transportation models, travel time and vehicle operating cost models, noise and air pollution models. Three unique characteristics are established: the zonal impact analysis framework, the impact interrelations in communities' viewpoints, and the community involvements in mitigating impacts. The system consists of four functions: problem and alternative identifications, impact assessments, impact integrations under public preferences, and information displays. As the results, most stakeholders prioritized pollutions (0.64) higher than travel costs (0.34). Therefore, planners should seriously consider the pollution problems. With the minimum impact costs, a shopping center project should be allocated into the radial network center. For two projects, they should be implemented beside the expressways. The proposed IZIA system was a successful preliminary application.

**Key Words:** Integrated Zonal Impact Analysis, Planning Support System, Integrated Impact Assessment, Land Development Control.

## 1. INTRODUCTION

The transportation improvements and land-use controls of mega-urban regions in Asian developing countries have not kept pace with the economic and urbanization growths for years. The interdependence of urban forms and transportation networks has been ignored, such as in Jakarta, Indonesia, and in Bangkok, Thailand. Definitely, the rapid urbanizations have not occurred in developing cities only, but also in the developed ones. However, planners in developed countries have matured various advanced planning techniques to deal with such their complex city growths. Their last efforts are the planning supporting system (PSS) developments since 1990s [Geertman and Stillwell, 2004]. While the problems of urbanization in developing cities have become more intensive than in developed cities, but their land and infrastructure planning processes are still unsystematic and ineffective. This results to the sprawl city developments together with substantial environmental damages and economic losses. Particularly in Bangkok Metropolitan Region (BMR), because of many land developments located without efficient control measures in suburban areas, Bangkok has been led to the auto-dependence city with severe traffic congestion spread from core districts to suburban districts.

More adverse impacts of uncontrolled developments are spread over urban areas, the efficient decision making on city planning is more difficult. This is because such impacts have been fallen into several fields of public concerns, such as congestion, pollutions, high costs of travels in the cities. The traditional planning approach in developing cities cannot effectively improve their destroyed living environments. The planners need more advanced techniques to deal with such complicated situations. This article aims to present an effort to initiate a better planning technique to assess and control the unfavorable consequences of land developments. The technique is called “Integrated Zonal Impact Analysis (IZIA) System”. It is expected to develop the IZIA system to be a PSS application for land development controls in Bangkok.

At first, the study reviews about the necessity of planning support system in land use and transportation planning in Bangkok. Next, an effort to develop the IZIA system as an application of PSS techniques is explained. The designed IZIA components are also discussed in details. To demonstrate the application of IZIA system, the study has applied it into a case study of Bangkapi District in Bangkok, Thailand. Finally, the findings are summarized in the conclusion part.

## 2. NECESSITY OF PLANNING SUPPORTING SYSTEM IN BANGKOK

Due to uncontrolled urban developments, the characteristics of urban growths and its undesirable impacts in Bangkok can be demonstrated into Figure 1. In the central areas, most land usages are the integrations for commercial and business buildings, so number of populations has been significantly increased in this area. Their road densities although are relatively high, severely congested traffic is easily experienced, because of exceeding travel demands. For surrounding areas of the central areas, they are dedicated for locating commercial areas and expanding residential areas. Due to low road densities, the accessibility of these surrounding areas is unsatisfied for commuters. Because of residential area expansions and lack of road spaces, more congested areas are formed in urbanized suburban residential areas. Travel time of road users is enormously increased. The last is the suburban areas to be urbanized in the forthcoming future. Many land subdivision development projects have been allocated, but they have not yet generated severe congestion in this area. However, there is the problem of insufficient facilities. As seen from the mechanism of city expansions, it can be imagined that Bangkok has to face the severe congestion together with damages of living standards. It was estimated that Bangkok commuters have to spend about 60 minutes for daily one-way working trips. Moreover, air and noise pollution problems become rigorous social issues, especially Total Suspended Particulate Matter (TSP) and Nitrogen Oxide (NOx) in the central areas and its surrounding areas.

While so many socioeconomic and environmental living problems have been imposed into the city, the land use and transportation planning process in Bangkok is not improved to catch up with these problems. As seen from the existing planning process in Figure 2, the transportation system has been considered as an inactive component. The effects of land use changes on networks, such as trip generations, are not taken into account for land development controls. Most planning tools are just the data collection from field surveys, simple statistic analysis, development of a future plan based on the comments and discussion of planners. There is no an advanced process to evaluate the positive and negative impacts of designed plan. Most identification of allowable land use types in the zoning regulation is just based on the existing activities, and the physical conditions of networks. The master land use plan is one of important matters in the city-planning field, but it is weakly planned in Bangkok. As the results, many living problems of people become more severe. In addition, Bangkokian planners must concern the participation of community, since at present Thai

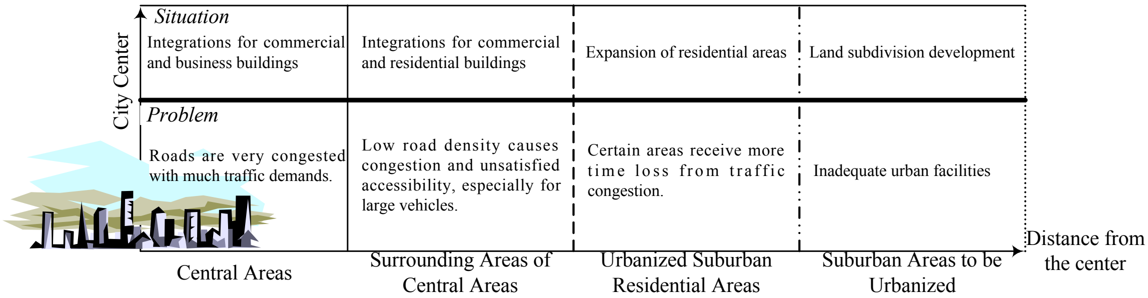


Figure 1. The Urban Growth Characteristics in Bangkok and Its Undesired Outcomes.
Source: Combined from JICA and BMA (1997).

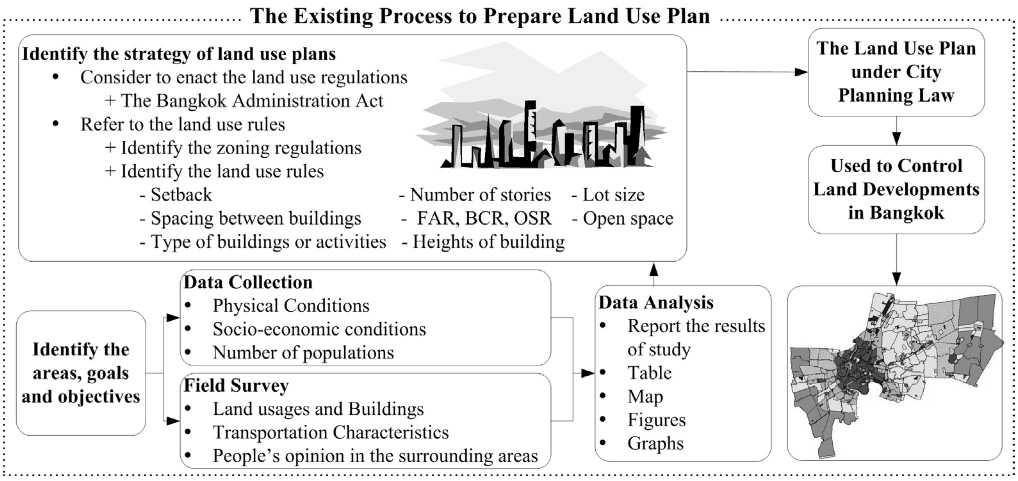


Figure 2. The Existing Land Use Planning Process in Bangkok.
Source: DCP (2004)

society thinks of the social needs more seriously. As seen from the Eight National Economic and Social Development Plans (1997-2001), it requested to include the public involvements into the planning process. However, the way to include this issue is ambiguous.

Under the mentioned problems, the decision-making in the urban planning of Bangkok becomes more difficult, because so many issues must be considered. Without a powerful planning system, it is almost impossible to mitigate those problems. Planning Support System (PSS) is one of alternatives to enhance the planning performances in multi-stipulations, especially in the city lacking a systematic and powerful planning system. PSS can facilitate data management, analysis, problem solving, design, decision-making, and communication activities [Nedovic-budic, 2000]. Based on these PSS capabilities, the PSS technique can be expected to support Bangkokian planners to deal with such complicated problems more effectively. With getting faster in improving technology utilizations and human resource developments in a number of planning agencies in Thailand, it is cautiously optimistic to initialize a PSS development for the land use and transportation planning [Kammeier, 1998]. At least, provisions of some basic ideas, necessary data, and experiences through case studies can stimulate and accelerate developments of such planning techniques.

Based on mentioned necessity to initiate PSS impression and development in the Thai planning society, this study proposes Integrated Zonal Impact Analysis (IZIA) System to plan for balancing land developments and transportation capacities serving for each city area. In the next section, the IZIA system development is described in details.

## 3. THE INTEGRATED ZONAL IMPACT ANALYSIS SYSTEM

Due to the rapid and dramatic urban developments, the integration of land use and transportation planning is difficult to be implemented in poorly planned cities. Planners have tried for impact assessment frameworks in dealing with this problem. Generally, to assess the impacts of urban land developments on transportation systems can be classified into two levels, macro and micro levels, as shown in Figure 3. The macro level focuses on the whole city areas, most actions are considered as Policies, Plans and Programs (PPPs). The appropriate approaches include Environmental Impact Assessment (EIA), Strategic Environmental Assessment, and Integrated Impact Assessment. These macro analyses are often utilized to develop master land use and transportation plans. In the opposite, the micro level aims to assess impacts of an isolated development project, or Project-Base. It is appropriate for specific part of city. In project-base, Traffic Impact Assessment under EIA, Development Impact Assessment, and Community Impact Assessment, is mainly employed to control and relieve the impacts at local or site area. Since actual urbanizations are resulted from simultaneous developments in many places, the approaches of micro level are unsuitable for comprehensive planning. While transportation planners focus on macro and micro scales, land use zoning system controls land usages at zonal scale or mezzo level. This has generated a gap between land use and transportation planning at the mezzo scale, and resulted to the ineffectiveness of planning coordination, especially in developing cities. To fulfill this gap, this study intends to develop a Planning Support System for impact assessment approach in zonal level, namely Integrated Zonal Impact Analysis (IZIA) System.

Basically, three sets of ideas and functions are combined to form a framework of planning support systems. First, it is a structure consisting of various models or systematic concepts of interests and its problem which planning aims to resolve. The second is a system providing various informative data through analysis, prediction and prescription for a studied problem. Third, it involves the systems used to transform basic data or analysis results into information and communication system. This also includes presentation of modeling, and design [Harris and Batty, 1992]. Regarding to these functions, the IZIA system has been developed to attack the problems of adverse impacts caused by land developments in Bangkok. Four sets of functionalities are defined, including problem and alternative identifications, impact assessments, impact integrations based on public participation, and information displays, respectively. These functionalities can be illustrated in Figure 4. The details are explained based on the basic ideas and framework in all functionalities.

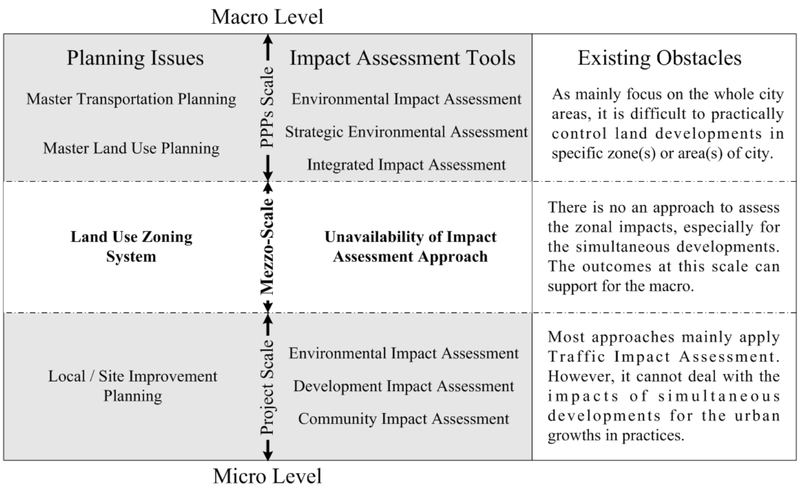


Figure 3. The Impact Assessments Approaches for Land Use and Transportation Planning.

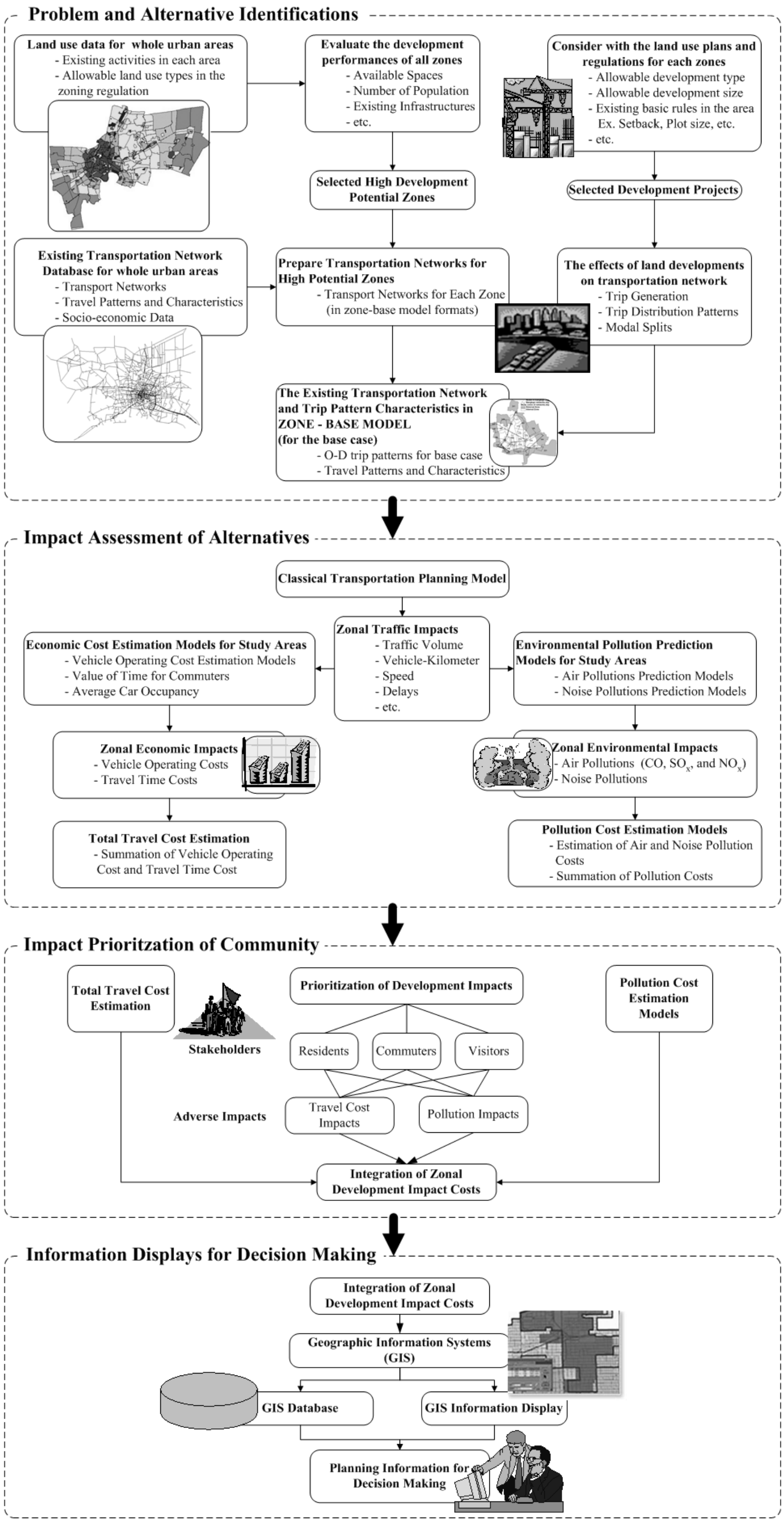


Figure 4. The Functionalities of Integrated Zonal Impact Analysis (IZIA) System

## 3.1 Problem and Alternative Identifications

The purpose of the problem and alternative identification functionality is to build up the databases that contain all the geographic and non-geographic data about the study area and its surroundings. Actually, to properly perform this task, this functionality should be developed into a database system and be able to exchange the data with different sources. The data is useful for understanding the current situation of study area, and also for identifying the problems between land use and transportation planning in each sub area. This step helps planner to define suitable goal(s) and objective(s) for the plan development process. Under the defined goals, number of solutions or plan alternatives can be generated. These planning tasks are based on the concept of sketch planning. Nowadays, there are a lot of efforts to develop the automatic generation of plan, but it is still far from reality.

Since the land use database in Bangkok is not available for the public yet, this study has to conduct the field survey and develop our own land use database. The land use planning reports of related organizations are also necessary to be reviewed. The functionality aims to investigate the performances of land developments in each urban zone based on the zonal characteristics, including available space, number of population, existing infrastructures etc. All zones should be included into the evaluation to investigate the directions of the developments. The high potential zones are considered to develop plan alternatives. Moreover, types, sizes, and other characteristics of development projects should be included into the analysis. Additionally, as the existing transportation network database is for whole urban areas, so it needs to be modified into the zone-base model. The networks have to be classified and kept into the zones that they are located. The present conditions of urban travel characteristics, including origin-destination distribution patterns, mode splits, etc, are utilized to compare and evaluate the effects of development alternatives on the transportation systems.

### 3.2 Impact Assessment of Alternatives

This functionality works as the analysis process consisting of various planning models in estimating undesired impacts of proposed land usages. Two development impacts generated by new traffic are considered in this study, including economic and environmental impacts. The economic impacts include vehicle operating and travel time costs, for the environments they focus on traffic noise and air pollutions. The air pollutions consist of Carbon Monoxide (CO), Nitrogen Oxide ($NO_X$), and Sulfur Dioxide ($SO_2$). It can be seen that to assess these adverse impacts require many impact estimation models. First, 4-steps or classical transportation planning model is employed to quantify traffic impacts, such as vehicle-delays, vehicle-kilometers, etc. These traffic impacts are utilized to assess the environmental and economic secondary impacts by using prediction models, such as noise and air pollution models, vehicle operating cost estimation model, and value of time, in the further assessments. All assessments must be performed in the zone-base model. Moreover, some data in the study area must be able to be imported or exported from these impact models, for example noise pollution models requiring some physical input data like road widths, distances between the buildings and road edges, as shown in Figure 5. As all impacts must be integrated together at the end of process, so the quantities of pollution impacts must be estimated in monetary term, so pollution cost estimation models are also indispensable. These models have been collected and evaluated from many researches conducted in Bangkok, only the most suitable ones can be applied for this study. However, the detail of each model is out of scope of this paper.

### 3.3 Impact Integrations Under Public Preferences

Because various adverse development impacts have been imposed into city areas, the issue of integrated appraisals becomes important when confronting about a livable city. However, the way to integrated impacts is still under the examinations. Most traditional approaches disregard the interrelationship between the impacts. Therefore, the integrated impacts cannot

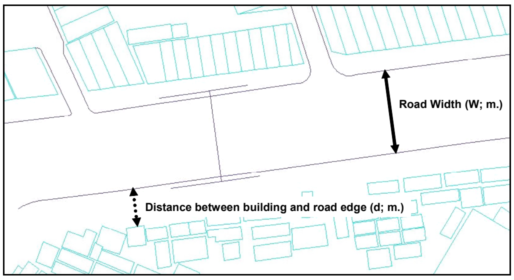


Figure 5. Physical Data of Road Networks for Noise Prediction Models

reflect the actual needs of society. At the same time, most stakeholders nowadays have been increasing their awareness to participate in managing land developments and transportation improvements. These drive this study to consider the impact integration based on public preferences. Three stakeholder groups, including residents, commuters, and visitors, are asked to prioritize two kinds of impacts, consisting of travel cost and pollution impacts, as demonstrated in Figure 4. There was no doubt to include residents as the stakeholders, because the development impacts directly affect to their diary lives. For the commuters, although they do not live in the area, but they have to go in and go out almost everyday, so the impacts on the networks can significantly influence their regular trips. The visitors were included, as communities need to interact each other through transportation networks, so they should be concerned to provide their convenient travels. The impact priorities and quantities of impacts are utilized to integrate all impact costs. These integrated impact costs represent for total impact costs imposed into each zone. Total impact costs for whole study areas in each alternative are employed to find out the most suitable development alternative. The zonal impact costs are also useful to clearly present the zonal impact distributions. This provides the informative data for planner to efficiently make a decision on implementing an appropriate land development form and on mitigating critical impacts.

### 3.4 Information Displays for Decision Making

One of PSS advantages from using advanced technologies is the powerful visualization of analysis results, especially using Geographical Information System (GIS). The current applications have been dedicated to visually accessible or interactive inputs and outputs. The developed IZIA system in this study utilizes GIS database, keeping the analysis results and geographical data, and the GIS visualization system to demonstrate the PSS interface of zonal impact distribution. This can provide some informative data for decision-making. In particular, the distribution of zonal development impacts is very helpful in identifying critical zone affected by development project, and in providing some mitigation measures.

Next, these functionalities of IZIA system are applied into Bangkapi District, as a case study.

## 4. A CASE STUDY OF BANGKAPI DISTRICT IN BANGKOK

Bangkapi area is located in the middle of two development directions of Bangkok, the North and Southeast, and covers the areas of 48.904 km$^2$. There are three reasons for selecting Bangkapi as a case study. First, it is one of high potential development areas in Bangkok with various activities, including education, business, and commerce. There are many main transportation facilities implemented, particularly for the Ramintra-Atnarong expressway, Ramkamhang, Nawamin, Serithai, Srinakarin, and Ladproa roads. These networks promote

Bangkapi to be a business and activity center as shown in Figure 6. Second, due to lack of efficient land use control measure in Bangkapi, it results to generate many shopping centers and markets established along the roadsides of main routes with severe congestions, especially during peak hours. In addition, the levels of noise and air pollutions are very critical, so it should find some measure to control or alleviate these adverse impacts. Third, it is the advantages of data acquisitions, including transportation network databases, the models and parameters for estimating other impacts. The necessary networks and travel data in this research was available from the Transport Data and Model Center Project [OCMLT, 2000].

### 4.1 Land Development Alternatives

Regarding to the current land use and transportation databases, Bangkapi areas are separated into 14 zones, from Zone 167 to 180 as shown with population in each zone in Figure 7. In Bangkapi, the agricultural areas and vacant spaces are about 15.46 % of total areas. This represents that most Bangkapi areas were dedicated for buildings and activity areas. Based on the location of Bangkapi and its infrastructure performances, it is obvious that Bangkapi has fully potentials for land developments. Especially, it plays the role as the transition zone to connect between inner and outer Bangkok areas in the eastbound approach [DCP, 2002]. In the Bangkapi land use plan by Bangkok Metropolitan Administration (BMA), planners have planned to develop Bangkapi Business Center as the main center in this area. As explained before, this plan had been developed from the physical conditions, without detailed impact analyses of developments on infrastructure capacities. During data collection in this study, a shopping center project was just constructed in Zone 168 without any traffic impact assessment on adjacent networks. The study realized that this could be was a good case study to demonstrate to planners that without good planning process how much is effective for their decision. Therefore, the study team conducted the field surveys and considered the present characteristics of each zone, such as number of populations, present land use conditions, provided infrastructures, available spaces etc., to investigate the potential zones. Eventually, three potential zones, including Zone 168, 173, and 179, were selected for demonstrating the IZIA application as illustrated in Figure 7. As the consequences of expanding transport networks, Ramintra-Atnarong expressway, it can be expected that the zone next to this expressway, Zones 168, will be built up in the forthcoming future. For Zone 173 and 179, as they are located near the center of radial network in Bangkapi areas, and also in the promoted areas of Bangkapi Business Center, there was no doubt to include them in the evaluation.

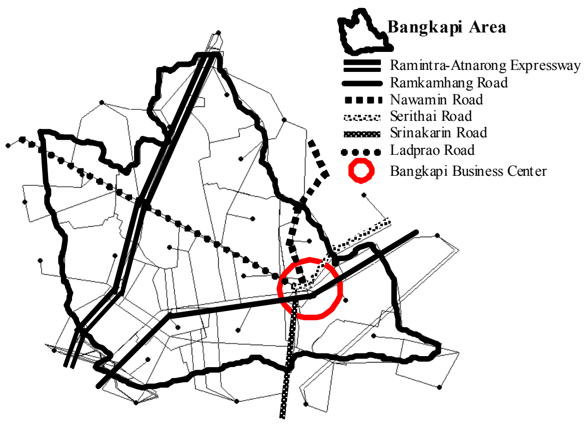


Figure 6. The Networks of Bangkapi Areas.

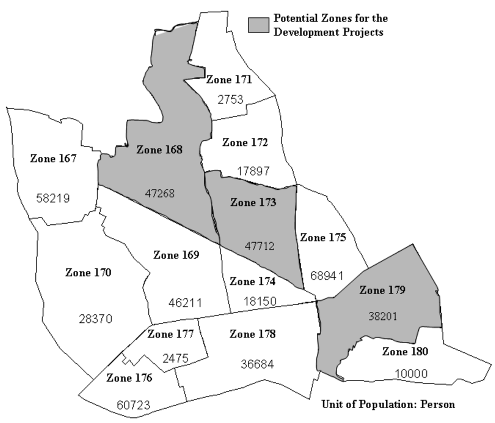


Figure 7. Populations and Locations of Zones

Consider a similar shopping center project, its project characteristics can be summarized into

Table 1. To cover all realistic and possible development cases, not only the cases of single development in a single zone were considered, but the cases of simultaneous developments, often occurred in Bangkok and other developing Asian cities, were also included as shown in Table 2. All simultaneous development cases refer to the same type and size of projects in order to determine the real effects of transportation capabilities in serving travel demands of each zone. These cases are simulated and analyzed into the steps of traffic simulations, and impact assessment and analysis, respectively.

Table 1. The Characteristics of Shopping Center Project

| Item | Information |
|---|---|
| Type of Land Use | Shopping Center |
| Gross Floor Area ($m^2$) | 200,000 |
| Predicted Generated Trips during Evening Peaks (car/100 $m^2$/ day)*<br>- For weekday | 2.92 |
| Deciding Factors for Estimation<br>- Land use unit as activity measure<br>- Other determinant factor | <br>Floor Area<br>Not Considered |
| Service Hours -10:00 AM-10:00PM (hours/day) | 12 |
| Assumption of New Traffic | Yes |
| Assumption of Primary Trips | Yes |
| Peak Hour Selection | Evening Peak of Road Traffic |

*Source: Chaiyasate (2000)

Table 2. The Analysis Cases of Development Impact Analysis

| Type | Group | Analysis Case | Zone 168 | Zone 173 | Zone 179 |
|---|---|---|---|---|---|
| Single Development | One Project | Case No. 1 | + | | |
| | | Case No. 2 | | + | |
| | | Case No. 3 | | | + |
| Simultaneous Developments | Two Projects | Case No. 4 | + | + | |
| | | Case No. 5 | + | | + |
| | | Case No. 6 | | + | + |
| | Three Projects | Case No. 7 | + | + | + |

Note: + means that the development project implemented in the zone.

### 4.2 Impact Assessments on Transportation Networks

Transportation Planning Simulation Program has been developed for this study to simulate traffics in each case. All traffic impacts were estimated in zone-base, and utilized to estimate the secondary impacts. The estimated impacts can be described in the following sub sections.

Air and Noise Pollution Impacts

To estimate noise pollution levels generated by traffics, various traffic noise prediction models applied into Bangkok were reviewed. Eventually, the models of interrupted flow were selected to predict the noise level in $L_{eq}$ for 1 hr., because of the accuracy of predicted results [Buranatrakul, 1995]. Moreover, the models had been developed from the same study areas also. For predicting air pollutions, the study employed the emission rates of CO, $NO_X$, and $SO_2$ varied for flow speed. These emission rates were estimated from vehicles under the real traffic streams in Bangkapi areas [Angkoonwatthana, 1997]. The results of noise and air pollution estimations can be illustrated in Table 3. To calculate zonal noise levels, the average noise level from all links in a zone was estimated by weighting with traffic volumes on each link. The zonal quantities of air pollutions were the summations of the pollutions emitted on each route in a zone. These processes of pollution estimations have been programmed in MATLAB Program. The program can directly use the traffic results simulated from the previous step and the physical data from the GIS database, because the data inputs and outputs in the IZIA system have been formatted from the designing step.

Table 3. The Noise and Air Pollution Levels from Each Development Case

| Case | Pollutions | Pollution Levels in each zone of Bangkapi areas | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | |
| No. 1 | Noise | 82.70 | 80.59 | 80.31 | 78.59 | 77.80 | 78.25 | 82.78 | 84.29 | 82.82 | 79.91 | 84.12 | 82.89 | 79.56 | 73.72 | 80.60 |
| | CO | 15.65 | 71.30 | 19.64 | 52.41 | 10.85 | 2.23 | 20.02 | 5.11 | 32.31 | 33.00 | 29.25 | 57.29 | 17.79 | 14.31 | 381.16 |
| | $NO_X$ | 2.68 | 11.90 | 3.44 | 8.51 | 1.82 | 0.40 | 3.54 | 0.92 | 5.71 | 5.60 | 5.26 | 10.16 | 3.04 | 2.18 | 65.16 |
| | $SO_2$ | 0.05 | 0.18 | 0.07 | 0.11 | 0.03 | 0.01 | 0.07 | 0.02 | 0.12 | 0.09 | 0.11 | 0.21 | 0.05 | 0.01 | 1.13 |
| No. 2 | Noise | 80.83 | 80.40 | 81.17 | 79.36 | 78.07 | 78.60 | 83.18 | 83.98 | 82.77 | 79.13 | 84.11 | 82.61 | 78.96 | 75.07 | 80.59 |
| | CO | 14.07 | 72.32 | 18.54 | 55.89 | 10.56 | 2.39 | 19.91 | 4.81 | 31.42 | 27.69 | 31.56 | 56.57 | 17.71 | 15.80 | 379.24 |
| | $NO_X$ | 2.32 | 12.10 | 3.23 | 9.33 | 1.74 | 0.43 | 3.58 | 0.87 | 5.48 | 4.76 | 5.64 | 10.02 | 2.96 | 2.42 | 64.88 |
| | $SO_2$ | 0.03 | 0.18 | 0.06 | 0.14 | 0.02 | 0.01 | 0.08 | 0.02 | 0.10 | 0.08 | 0.12 | 0.20 | 0.04 | 0.02 | 1.10 |
| No. 3 | Noise | 80.89 | 80.54 | 81.34 | 79.22 | 77.45 | 78.21 | 82.53 | 83.94 | 82.78 | 78.75 | 83.87 | 82.59 | 80.09 | 74.16 | 80.45 |
| | CO | 14.30 | 69.56 | 20.15 | 55.09 | 9.35 | 2.19 | 19.72 | 4.79 | 32.22 | 26.69 | 30.02 | 54.70 | 17.03 | 13.84 | 369.65 |
| | $NO_X$ | 2.36 | 11.71 | 3.55 | 9.06 | 1.55 | 0.39 | 3.48 | 0.86 | 5.59 | 4.50 | 5.37 | 9.70 | 2.94 | 2.10 | 63.16 |
| | $SO_2$ | 0.03 | 0.19 | 0.07 | 0.12 | 0.02 | 0.01 | 0.07 | 0.02 | 0.10 | 0.07 | 0.11 | 0.20 | 0.05 | 0.01 | 1.07 |
| No. 4 | Noise | 81.28 | 80.56 | 80.21 | 78.48 | 77.40 | 77.60 | 82.97 | 84.11 | 82.77 | 79.64 | 83.97 | 82.84 | 79.69 | 74.29 | 80.42 |
| | CO | 14.81 | 66.17 | 18.51 | 49.69 | 10.09 | 1.96 | 19.58 | 5.06 | 31.93 | 34.00 | 28.96 | 54.99 | 19.27 | 12.90 | 367.92 |
| | $NO_X$ | 2.47 | 11.32 | 3.26 | 8.08 | 1.69 | 0.35 | 3.46 | 0.91 | 5.65 | 5.55 | 5.20 | 9.73 | 3.20 | 1.97 | 62.84 |
| | $SO_2$ | 0.04 | 0.20 | 0.07 | 0.10 | 0.03 | 0.01 | 0.07 | 0.02 | 0.11 | 0.07 | 0.11 | 0.20 | 0.05 | 0.01 | 1.09 |
| No. 5 | Noise | 81.69 | 80.77 | 81.32 | 78.95 | 77.95 | 77.37 | 83.05 | 83.58 | 83.34 | 79.49 | 83.86 | 82.58 | 80.00 | 74.48 | 80.60 |
| | CO | 16.73 | 73.59 | 17.58 | 54.00 | 11.21 | 1.85 | 20.35 | 4.75 | 30.94 | 28.93 | 30.23 | 55.06 | 17.74 | 15.08 | 378.04 |
| | $NO_X$ | 2.82 | 12.33 | 3.07 | 8.79 | 1.87 | 0.33 | 3.60 | 0.85 | 5.54 | 4.96 | 5.41 | 9.78 | 3.06 | 2.29 | 64.70 |
| | $SO_2$ | 0.04 | 0.19 | 0.06 | 0.11 | 0.03 | 0.01 | 0.07 | 0.02 | 0.12 | 0.09 | 0.12 | 0.20 | 0.05 | 0.01 | 1.12 |
| No. 6 | Noise | 81.74 | 80.56 | 80.46 | 78.73 | 78.03 | 78.42 | 83.31 | 84.59 | 83.67 | 79.16 | 84.41 | 82.97 | 80.41 | 74.66 | 80.79 |
| | CO | 13.11 | 71.09 | 19.07 | 52.54 | 11.09 | 2.34 | 19.54 | 6.30 | 33.94 | 29.00 | 33.32 | 60.22 | 18.28 | 16.96 | 386.8 |
| | $NO_X$ | 2.25 | 11.94 | 3.34 | 8.53 | 1.86 | 0.42 | 3.51 | 1.13 | 6.02 | 4.92 | 5.99 | 10.70 | 3.18 | 2.56 | 66.35 |
| | $SO_2$ | 0.04 | 0.19 | 0.06 | 0.11 | 0.03 | 0.01 | 0.08 | 0.02 | 0.12 | 0.08 | 0.13 | 0.22 | 0.06 | 0.01 | 1.16 |
| No. 7 | Noise | 81.84 | 80.62 | 81.02 | 78.97 | 78.16 | 78.07 | 82.42 | 83.70 | 83.14 | 78.97 | 84.18 | 82.74 | 80.66 | 74.78 | 80.66 |
| | CO | 13.82 | 73.60 | 18.67 | 54.47 | 11.68 | 2.20 | 17.97 | 4.70 | 32.33 | 28.32 | 32.07 | 57.03 | 18.69 | 16.55 | 382.1 |
| | $NO_X$ | 2.34 | 12.31 | 3.25 | 8.86 | 1.96 | 0.40 | 3.17 | 0.85 | 5.74 | 4.77 | 5.76 | 10.11 | 3.32 | 2.73 | 65.57 |
| | $SO_2$ | 0.04 | 0.19 | 0.06 | 0.11 | 0.03 | 0.01 | 0.06 | 0.02 | 0.12 | 0.08 | 0.12 | 0.21 | 0.07 | 0.04 | 1.16 |

Units of noise level and air pollutions: dBA and kilogram per hour.

It was found that the results of pollution impacts were not obviously different in each zone for each development alternative. This might be because numbers of trips generated by new land uses were too small, so it did not significantly change zonal pollution levels in each alternative. Without any land development, the existing noise level on Ramkamhang road is about 76.6 – 77.4 dBA, considerably higher than 70 dBA, the acceptable maximum standard of Thailand [PCD, 2002]. This implies that noise pollutions in Bangkapi are very dangerous for the hearing abilities of people, especially it has been occurred along daytime and nighttime. The pollutions resulted from the IZIA system pointed out that zonal noise levels in all cases are worsened, as shown by the noise levels of zones nearby Ladprao, Serithai and Ramkamhang Roads, they include Zone 167, 168, 169, 173, 174, 175, 177, and 178. These roads are the trunk routes for distributing trips in Bangkapi, thus a lot of traffics go through them together with congestions and severely emitting pollutions, particularly in evening peak period.

Regarding to the air pollutions, the existing average levels of dispersed CO, $NO_X$, and $SO_2$ in an hour on Ladprao road are 0.0 - 8.7 ppm, 0.0 - 154.0 ppb, and 0.0 – 48.0 ppb, respectively. The existing air pollution concentrations could not be compared with the pollution emissions estimated in this study, but they could be considered with the Thai standards. It found that CO and $SO_2$ are much lower than the acceptable levels (30 ppm and 300 ppb, respectively). For the range of $NO_X$ pollution, it is slightly lower than the standard, 170 ppb, so it should be carefully considered in the impact assessment. Based on the IZIA system, the overall air pollutions estimated were quite high in Zone 168, 170, 175, 177, and 178. As Ramintra-Atnarong expressway is located in Zone 168 and 170, so most travelers journey through these two zones, and it causes to generate a lot of air pollutions. In Zone 177 and 178, their networks are connected between the expressway and Bangkapi Business Center, so many trips pass through them, and create the pollutions. Zone 175 is located in the center, and also two main roads, Nawamin and Serithai, are established in the zone, therefore it cannot avoid traffic jams and excessive pollutions. In addition, it was very evident that the levels of $SO_2$ were very low. This is because the Thai government has tried to decrease the proportion of Sulfur in diesel oils for long times, so its level could be reduced significantly.

Travel Cost Impacts

To estimate travel costs, the value of time and vehicle operating cost estimation models, developed by Department of Highway, Thailand [DOH, 2001], were applied into the study. It was estimated that in 2003 the values of time for working or educational trips, and non-working trips are 59.603, and 14.903 Baht/hour/person, respectively. The average car occupancy rate for Bangkok is about 1.4 passenger/car. The total travel costs consisting of travel time and vehicle operating costs were estimated for each zone as shown in Table 4.

The travel costs of Zone 168, 170, 177, and 178 were substantial compared to the others, because they are located in the main travel streams of Bangkapi areas with provided high performance networks like the expressways in Zone 168 and 170. Most commuters have to spend their time and money for passing through these zones. Zone 169, 173, 175, and 176 are also imposed by large zonal travel costs, since they are located on trunk routes. These results seem to be similar with the anticipated traffic pollutions. It is very obvious that the existing travel conditions in the areas have influences on pollution and travel cost impacts of any proposed development project.

Table 4. The Total Travel Costs from Each Development Case (Unit: Baht 1,000 per hr)

| Case | Travel costs in each zone of Bangkapi areas | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | |
| No. 1 | 390 | 1,396 | 510 | 1,034 | 236 | 70 | 509 | 178 | 716 | 727 | 773 | 1,399 | 408 | 229 | 8,576 |
| No. 2 | 308 | 1,417 | 480 | 1,210 | 206 | 75 | 516 | 169 | 690 | 648 | 846 | 1,380 | 368 | 281 | 8,594 |
| No. 3 | 313 | 1,387 | 525 | 1,113 | 184 | 70 | 487 | 170 | 689 | 587 | 753 | 1,341 | 383 | 220 | 8,222 |
| No. 4 | 329 | 1,365 | 488 | 993 | 222 | 64 | 509 | 179 | 710 | 712 | 745 | 1,342 | 390 | 216 | 8,263 |
| No. 5 | 362 | 1,457 | 453 | 1,076 | 247 | 61 | 519 | 168 | 708 | 673 | 808 | 1,368 | 398 | 268 | 8,565 |
| No. 6 | 311 | 1,400 | 484 | 1,034 | 242 | 80 | 481 | 199 | 793 | 549 | 833 | 1,457 | 419 | 258 | 8,540 |
| No. 7 | 323 | 1,445 | 488 | 1,092 | 257 | 70 | 465 | 167 | 745 | 534 | 798 | 1,415 | 447 | 306 | 8,553 |

### 4.3 Impact integrations based on public participation

Normally, the groups mainly influencing on land use and transportation planning in Bangkok or other developing cities are planners and developers. This condition is changing to increase roles of the third party, Communities. According to unpleasant consequences of uncontrolled urban developments in degrading living environments, most people have increased their awareness to participate in planning for their neighborhoods. Nevertheless, the role of stakeholders is still an inactive catalyst in the decision making step. Sometime, a government plan or strategy does not correspond to the authentic social needs. The IZIA system has been designed to include the public opinions and preferences into the impact assessment process and the preparation of mitigation measures. To estimate the real values of impacts in the public senses, the study integrated travel cost and pollution impacts based on the public preferences. This is because we realized that just estimate environmental impact costs and directly combine with travel cost impacts cannot represent the genuine significances of such development impacts. Certainly, not only the preferences of society are necessary, their attitudes or opinions on mitigating impacts are very important in alleviating impacts effectively also.

To collect such public preferences and opinions, the study performed the questionnaire surveys by classifying stakeholders and zones. This is useful for investigating the influences of stakeholder group and zone on impacts and its alleviations. All data must be gathered to develop a database system linked with the impact assessment process and provision of mitigation measures in the further steps. In this article, it only focuses on using the impact priorities evaluated by stakeholders in integrating impacts. The Analytic Hierarchy Process (AHP) method was utilized to estimate the impact priority. Totally, 1,450 questionnaires were distributed into 14 zones Bangkapi areas, and 1,064 questionnaires were returned, after verifying data, only 972 samples were qualified.

Any respondents were asked to weight that between travel costs increases and traffic pollution increases caused by a land development project, which one is more serious or important for their communes. As the results, most of people in all zones considered the pollution impacts more importantly than the travel costs as shown in Figure 8. The priorities of pollution impacts in all zones were higher than 0.60. To investigate the influence of people's zonal living conditions on the preferences, the independence test by Chi-squared Tests ($\chi^2$-Tests) was applied. As shown in Table 5, the null hypothesis was accepted, because Asymptotic Significance (Asymp. Sig.) is higher than the significance ($\alpha$: 0.05). It means that the stakeholders' preferences were not influenced by the zonal living conditions. This was obviously seen from the cluster analysis in Figure 9, most priorities were close each other, and could not be grouped. This result might be because people in different zones can experience traffic congestion with severe pollution problems in anyplace of Bangkapi District, so they similarly concern about it. The study thus estimated them by averaging from all stakeholders' preferences instead of estimating the priorities for each zone.

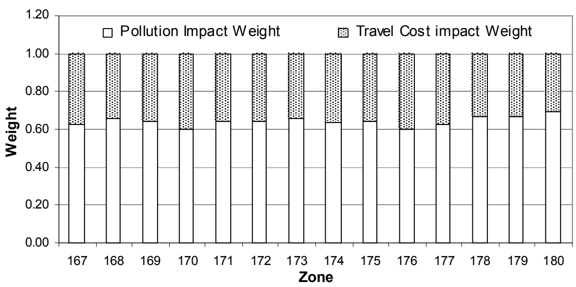


Figure 8. The Travel Cost and Pollution Impact Priorities in Each Zone.

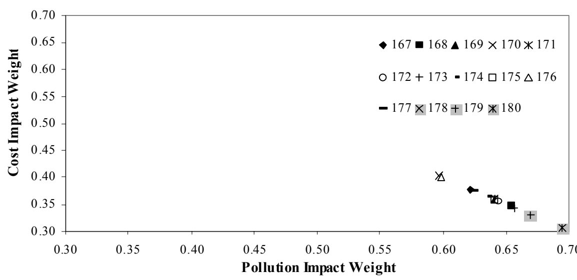


Figure 9. The Cluster Analysis of Impact Priorities from All Zones.

Table 5. The Independence Test for Impact Priorities on Zonal Conditions.

| Null Hypothesis ($H_0$) | Asymp. Sig | Testing Result |
|---|---|---|
| The public preferences on the importance of impacts generated by land developments are independent from the zones. | 0.958 | Accept $H_0$ |

The average priorities of pollution and travel cost impacts were 0.64 and 0.36, respectively. This can be interpreted that in the public sense the value of environmental impact is 1.78 (0.64/0.36) times of the value of economic impact. Therefore, the total impact costs based on the public preferences can be calculated by using Eq (1).

$$Total\ Impact\ Cost = Total\ Economic\ Impact\ Cost + 1.78 \times Total\ Pollution\ Impact\ Cost \quad (1)$$

### 4.4 Evaluation of Land Development Alternatives.

To find out the most suitable alternative, environmental and economic impacts had to be integrated based on Eq. (1). Before that, the study needed to estimate the noise and air pollution costs. A number of related researches in Bangkok were reviewed, and the appropriate cost units were collected. Finally, the estimated unit costs were 1,103.12 Baht/dBA/hr/km for noise, 0.95 Baht/kg for CO, 7.06 Baht/kg for $NO_X$, and 1.63 Baht/kg for $SO_2$, respectively [Rasagam, 1987, and DPU, 1991]. These unit costs were modified based on money exchanging rate and Gross Domestic Products (GDP). The integration of economic and environmental impact costs for all development cases can be demonstrated into Table 6.

Table 6. The Total Impact Costs of Each Development Case (Unit: Baht per hr)

| Case | Noise Costs | CO Costs | $NO_X$ Costs | $SO_2$ Costs | Total Pollution Impact Costs | Total Economic Impact Costs | Total Impact Costs |
|---|---|---|---|---|---|---|---|
| No. 1 | 16,075,712 | 362.09 | 459.98 | 1.83 | 16,076,535 | 8,576,092 | 37,192,323 |
| No. 2 | 16,075,873 | 360.28 | 457.99 | 1.82 | 16,076,693 | 8,594,122 | 37,210,636 |
| No. 3 | 16,059,588 | 351.17 | 446.04 | 1.77 | 16,060,387 | 8,222,212 | 36,809,701[a] |
| No. 4 | 16,047,730 | 349.52 | 443.80 | 1.76 | 16,048,526 | 8,262,778 | 36,829,156[b] |
| No. 5 | 16,093,037 | 359.13 | 456.84 | 1.83 | 16,093,855 | 8,564,700 | 37,211,760 |
| No. 6 | 17,586,234 | 362.71 | 468.49 | 1.89 | 17,587,067 | 8,539,922 | 39,844,901 |
| No. 7 | 17,628,384 | 355.77 | 498.17 | 2.23 | 17,629,240 | 8,658,830 | 40,038,874 |

a: The best alternative for single development.
b: The best alternative for simultaneous developments.

Consider the minimum integrated impact costs, for single development cases, Zone 179 of Case No. 3 was the most suitable area for a new shopping center (36,809,701 Baht per hour). As Zone 179 is located in the center of radial networks, there are the advantages of full accessibilities, so it could helps to relieve the impacts of a project. In simultaneous developments, two projects should be allocated in Zone 168 and 173 (36,829,156 Baht per hour), since the high network capacities of the expressway are available. There was no doubt that the worst case should be the implementation of Case No. 7, because of three projects constructed. The major development impacts were travel costs, because Bangkapi District is very congested area. The pollution impacts were not significantly affected, because various factors can affect to the pollution levels in the study areas, such as traffic volume and speed, land width, road length, etc, so only small development traffic might not significantly change the environmental conditions. However, the results pointed out the necessity to seriously and immediately reduce traffic pollutions.

Furthermore, the IZIA system has provided some informative planning data as shown in Figure 10, 11, and 12. Figure 10 shows how to adapt the plan to reach the reality, and to minimize the adverse impacts of uncontrolled developments. Figure 11 and 12 demonstrate the zonal impact distributions of the suitable single and simultaneous developments. If planners really want to limit only one shopping center project, it should be implemented in Zone 179 as the plan. They have to seriously mitigate the impacts in zone 168, 170, and 178. These three zones were imposed by very high impacts as shown in the zonal impact distribution of Figure 11. However, because of medium impacts, Zone 169, 175, and 177 should be considered as well. Certainly, the real growths are possibly different from the plan. For example, in this case a shopping center was already approved for Zone 168, not Zone 179. Under the assumption of indifferent travel characteristics and none of land use changes effecting on travel patterns, planner can improve their plan by allocating the following project into Zone 173. This will help to minimize the undesired development impacts. Without these analysis results, planners may allow to implement other projects into other zones that can create more severe impacts. Nevertheless, to permit the second project in Zone 173, planners should pay attention to alleviate the impacts not only for zone 168,169, 170, 175, 177, and 178, but they have to include Zone 176 into mitigation plans as shown in Figure 12.

| | In Plan | | In Reality | |
|---|---|---|---|---|
| | Single Development | Simultaneous Developments | Single Development | Simultaneous Developments |
| Zone 168 | | ● | ▲ | ▲ |
| Zone 173 | | ● | | ▲ |
| Zone 179 | ● | | | |
| | Time Frame | | Time Frame | |

● Implement as the plan ▲ Implement in the real situation

Figure 10. The Modification of Development Plan Based on the Plan and Reality.

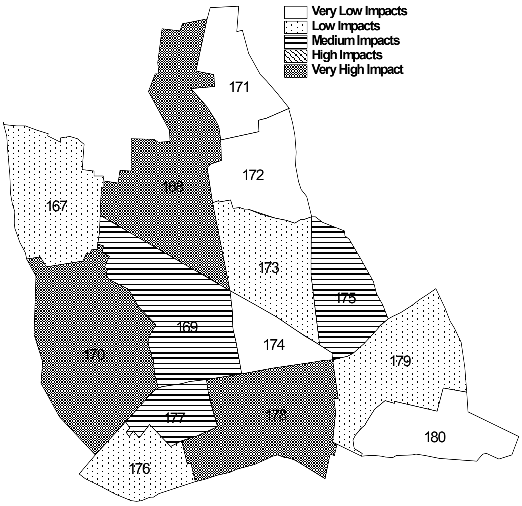


Figure 11. The Zonal Impact Distribution for a Development in Zone 179.

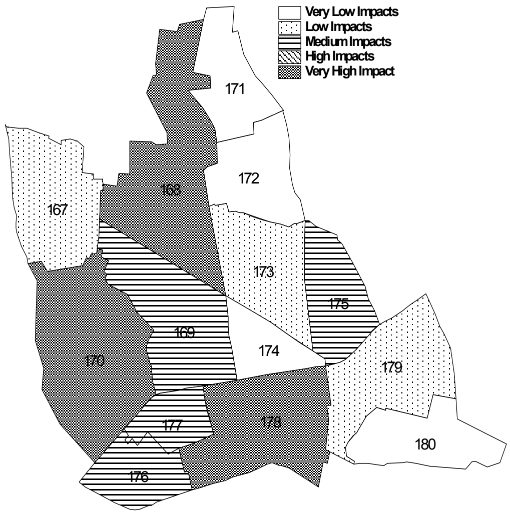


Figure 12. The Zonal Impact Distribution for Developments in Zone 168 and 173.

In the future, this study expects planners to apply the IZIA system to determine the impacts of land development capacities in all zones or areas in the city. The outcomes of simulation models in this PSS system can provide the informative data for three main evaluation tasks, including suitable location choices, size of development, and efficient identification of land use type for each area. It can be seen that these informative data are very useful in every decision-making stage of planning process, especially to develop an appropriate land use plan and to efficiently control land developments.

## 5. CONCLUSION

This paper presented an initial effort to develop the Planning Supporting System (PSS) for control land development impacts on transportation systems in Bangkok. The study has developed the Integrated Zonal Impact Analysis (IZIA) System with four main functionalities: problem and alternative identifications, impact assessments, impact integrations based on public participation, and information displays. These functionalities can be considered into three main PSS functions, as shown in Figure13. The function to structure various models based on the study interests is involved with the first two IZIA functionalities. While the function of providing a variety of information from the analysis is considered in the impact assessments and integrations, the provision of informative data for designing a plan is included in the information displays. The IZIA system was also designed to include an additional function that is how to promote the public participation in PPS system. This is located in the impact integration based on public participation. Moreover, The proposed IZIA has uniqueness on assessing the impacts at mezzo-scale or zonal level. This can coordinate between land development plan and transportation improvement more effectively. An alternative of impact integration was also proposed based on the public preferences so that the real value of development impacts can be presented through the assessments. Under the IZIA system the communities were encouraged to involve in the planning process, especially mitigating the adverse impacts. Through a case study of Bangkapi District, Bangkok, it was found that most stakeholders valued pollutions higher than travel costs, so planners should mitigate traffic pollution impacts seriously.

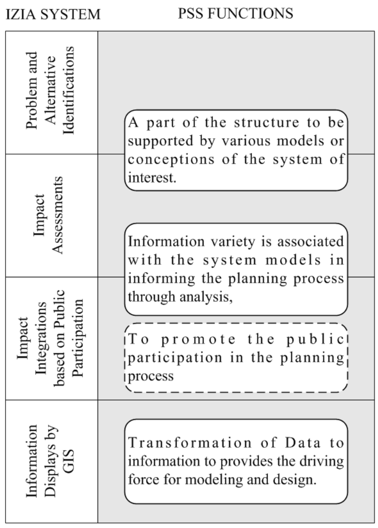


Figure 13. The PSS Functions in the Context of IZIA System.

It was recommended that a new shopping center should be allocated into the center of radial networks of Bangkapi, due to its high accessibilities. For two shopping center projects, planners should implement them into the zones beside the expressways, so the traffics could be effectively distributed. The IZIA system has provided some informative data to improve planning capabilities in weakly planned cities, such as how to include public preferences in impact assessment and integration, how to demonstrate clear zonal impact distribution for investigate critical area, etc. This information enhances the planning process to deal with rapid and dramatic urban developments effectively. However, the IZIA needs to be developed for many components in further steps, such as effectively plan alternative generation, automatically data transformation system, graphic user interfaces, and friendly user system.

From the study, it can be seen most required tools and necessary data of PSS are already at hand, not only in developed cities, but also in developing cities. What planners need to improve is how to design the process to fully and effectively integrate all of them. This is still under the explorations and waiting for planners in any cities to challenge.

## REFERENCES


Angkoonwatthana, P. (1997) Determination of emission factors of gaseous pollutants from different vehicle types in the inner and middle areas of Bangkok. A Master Thesis of King Mongkut's University of Technology, Thonburi, Bangkok. (in Thai)

Buranatrakul, T. (1995) Prediction of noise level due to the traffic in Bangkok Metropolis. A Master Thesis of Chulalongkorn University. Bangkok. (in Thai)

Chaiyasate, P. (2000) Trip generation from shopping centers in Bangkok Metropolitan Region. A Master Thesis of Kasetsart University, Bangkok. (in Thai)

Department of Highway, Thailand (DOH). (2001) The study of economic engineering, and environmental impacts for the project of highway connecting Hatyai, Thailand and Malaysia. (in Thai)

Department of Public Utilities (DPU). (1991) Air emission externality values adopted and purposed in various U.S. States, Massachusetts.

Division of City Planning (DCP) (2002) The report of the comprehensive land-use plan for Bangkapi District. Bangkok Metropolitan Administration. (in Thai)

Division of City Planning (DCP) (2004) The process of land-use zoning in Bangkok Metropolitan Region. Bangkok Metropolitan Administration. Access on: February, 2004
<URL: http://www.bma.go.th/dcp/>

Geertman, S. and Stillwell, J. (2004) Planning support systems: an inventory of current practice, **Computers, Environment and Urban Systems, Vol. 28**, 291–310.

Japan International Cooperation Agency (JICA) and Bangkok Metropolitan Administration (BMA). (1997) The Final Report: The Study on Urban Environmental Improvement Program in Bangkok Metropolitan Area.

Kammeier, H. D. (1998) A computer-aided strategic approach to decision-making in urban planning: An exploratory case study in Thailand, **Cities, Vol. 15 No. 2**, 105-119.

Nedovic`-Budic`, Z. (2000) Geographic Information Science Implications for Urban and Regional Planning, **URISA Journal**, **Vol. 12, No. 2**, 81-93.

Office of the Commission for the Management of Land Traffic (OCMLT). (2000) Final report: Transportation data and model center.

Pollution Control Department (PCD). (2002) The report of air and noise pollution survey. (in Thai)

Rasagam, G. (1987) Estimation of the social cost of noise and air pollution caused by road traffic in Bangkok. A Master Thesis of Asian Institute of Technology, Bangkok.