THE EXPERIENCE WITH USER FRIENDLY ENVIRONMENTAL EVALUATION SOFTWARE IN THE CITY OF KHON KAEN, THAILAND

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Abstract: The paper describes the use of two user friendly environmental evaluation software packages developed at the Transport Systems Centre, at the University of South Australia, and aspects of their application in the Asian context in the city of Khon Kaen, Thailand. A discussion is presented addressing the issues of environmental modelling in regional Asian cities and the differences between traditional "Western" models and problems encountered in the Asian environment. One of the models, SIMESEPT, is used to screen for potential problem areas within the Khon Kaen road network. This is achieved using the Knowledge-Based Expert System (KBES) component of the SIMESEPT package. The other model, NetNoise, is used to predict the distribution of noise originating from the road traffic network of the city and rigorously analyse these problem areas. NetNoise also provides some benefit to the user through its use as an educational tool and assists in exploring the various options available for traffic management in the city regarding noise amelioration. The unique distinctions between NetNoise and SIMESEPT will be described in detail and the potential factors contributing to the problematic areas in the Khon Kaen road network are also discussed. The outputs from the two packages can be used to prioritise detailed investigation or traffic calming schemes to the problematic areas in the road network. The MapInfo Geographical Information System (GIS) package has been used to integrate, store, manage, analyse, and display all geographical data, their associated attributes, as well as the analysed results derived from both NetNoise and SIMESEPT. GIS is an ideal tool for displaying the spatial distribution of traffic noise in relation to the road network of concern. NetNoise and SIMESEPT coupled with MapInfo can provide a new way of thinking about and a new means of analysis for handling traditional environmental problems.

1. INTRODUCTION

The use of computer software for environmental modelling has seen extensive improvements of late with the aid of Graphical User Interfaces (GUIs) and Geographic Information Systems (GIS). Many of these models have been created in the "Western World" based on models largely developed in Europe and North America. This paper looks at two such model software packages and their application to the Asian city of Khon Kaen.

Khon Kaen is located in the central north eastern region of Thailand (see Figure 1) and in 1994 contained a population of approximately 1.7 million of which 172,000 live in the Muang district. The agricultural sectors share in the Gross Provincial Product (GPP) has been steadily declining to the retailing, wholesaling, industrial, commercial and services sectors. Khon Kaen is currently one of the fastest growing cities in the Northeast due to its geographical location and government promotion of the city as a gateway to Indochina. Khon Kaen has been designated a regional institutional centre and is one of the nine main industrial cities in the country (KKU, 1997).

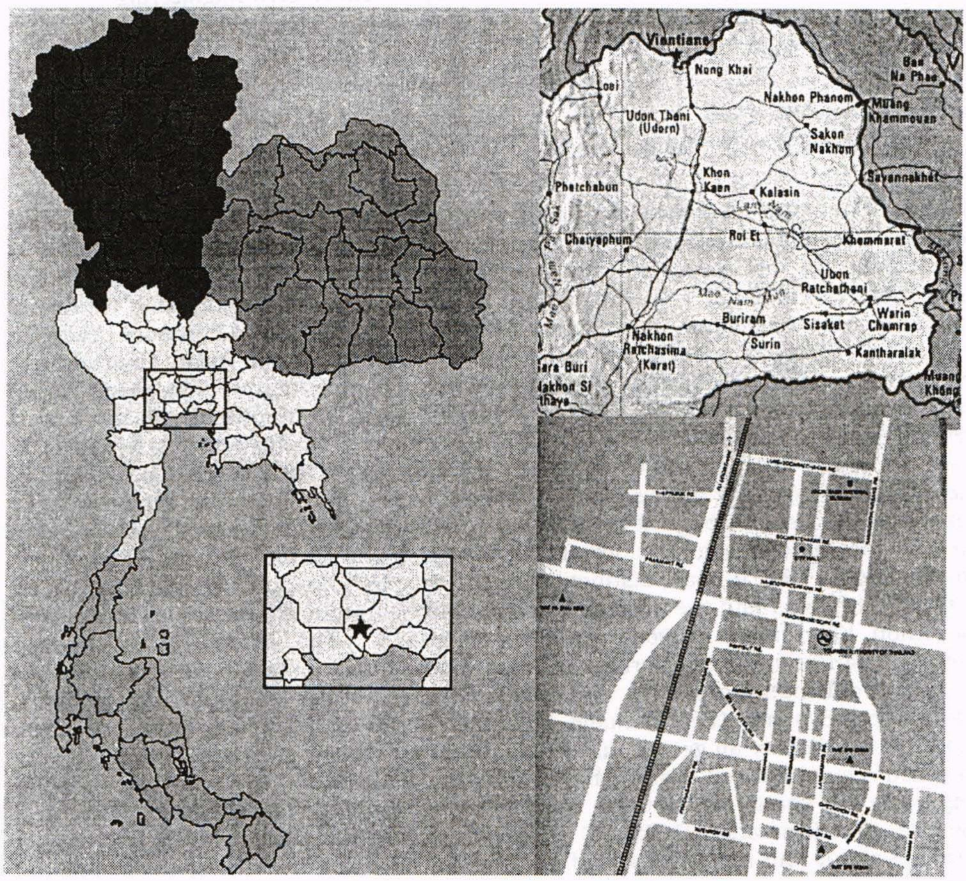

Figure 1. Maps showing the locality of Khon Kaen City in Thailand

In 1995 Khon Kaen possessed a total of 293.135 registered vehicles with an average annual growth rate of 18%. Of this, motorcycles constitute 73% of registrations follwed by passenger cars at 20%. As is common in many Asian cities, motorcycles feature prominently in the composition of the traffic. Passenger cars and motorcycles make up 43% of the on-road traffic while buses and heavy trucks constitute 4% and 3% respectively. The peak-hourly traffic volume is approximately 7.5% of the Average Daily Traffic (ADT) and average speeds are 18km/h within the Central Business District (CBD) and 35km/h within the inner suburbs (KKU and TC 1996). Figure 2 shows a typical street situation in Khon Kaen.

The economic growth, which in turn has fed the growth of motorised traffic has led to the inevitable problems associated with road traffic in built-up areas. Noise and air emissions along with difficulty of access and pedestrian safety have become increasing problems as is so commonly the case with such scenarios. An opportunity therefore existed for the authors to conduct some exploratory investigations into the impact of the traffic in Khon Kaen city.

Figure 2. Typical street environment in Khon Kaen

2. DATA COLLECTION AND REPRESENTATION OF THE KHON KAEN CITY ROAD NETWORK

2.1 Previous Studies

Recently, a study and data inventory of the current traffic and transportation conditions in the Khon Kaen city was conducted by the Department of Civil Engineering, Faculty of Engineering, Khon Kaen University in collaboration with the Transconsult Company (KKU and TC, 1996). This study was commissioned by the Thai Government and provides comprehensive data in terms of road physical and land use characteristics of the Khon Kaen road network (eg number of lanes, kerb-to-kerb road width, road class, adjacent land use type, etc) as well as some traffic-related data (eg peak hourly traffic flows (by vehicle classes)). In July 1997, one of the authors returned to Khon Kaen to adopt the road network as another case study. In addition to all available data from the recent study, field surveys were also carried out to gather some additional data.

2.2 Modelling The Khon Kaen Road Network

In most cases, road networks are stored in GIS and maintained by the local or government authorities. For Khon Kaen, an ARCINFO database was used as the basis for the input into the NetNoise model. Where no adequate GIS information is available, a network can be digitised in a GIS (in this case MapInfo was used) by using a suitable map or aerial photograph and the appropriate attribute data added to the GIS database. This exercise was completed for use with the SIMESEPT model (see Figure 3). These two options demonstrated the utility of GIS in traffic and environmental modelling.

Figure 3. MapInfo GIS street network for Khon Kaen overlaid with aerial photograph

The Khon Kaen CBD road network was adopted as a case study area with its road network covering an area of approximately three square kilometres in a grid-based system as shown in Figure 3. Based on the existing road hierarchy classification, the Khon Kaen road network was divided into four main categories, including (i) expressways or principle arterials, (ii) main arterials, (iii) collector roads, and (iv) local roads. Only the last three road categories exist in the Khon Kaen case study. However, for the purposes of this paper, only the main arterials and collector roads were investigated as their main function is to serve both the traffic mobility and access (frontage related activities) functions. In addition, this case study is concentrated on the determination of the traffic environmental impacts of all road links on the residents, pedestrians, and visitors who live or undertake their activities in the abutting land uses along these links. Difficulty of access, noise sensitivity, and pedestrian safety are selected as the important criteria for the case study.

For the SIMESEPT model, 11 main roads were selected and divided into 39 homogenous links consistent with the method used by Singleton and Twiney (1985) The traffic conditions (eg AADT, peak and off-peak hourly traffic flows, heavy-vehicle composition, and average speeds, etc) of each link were collected and estimated. The categories of the data used in the Khon Kaen case study include road physical characteristics, availability of pedestrian facilities, nature of parking restrictions, types and practicality of land use access, land use categories, existence of the opposite building facade, traffic conditions, and traffic management schemes. These data were refined and verified by using aerial photographs and other relevant documents (eg land use distribution map). The database was generated, integrated, and stored in a GIS (MapInfo) environment as shown in Figure 4.

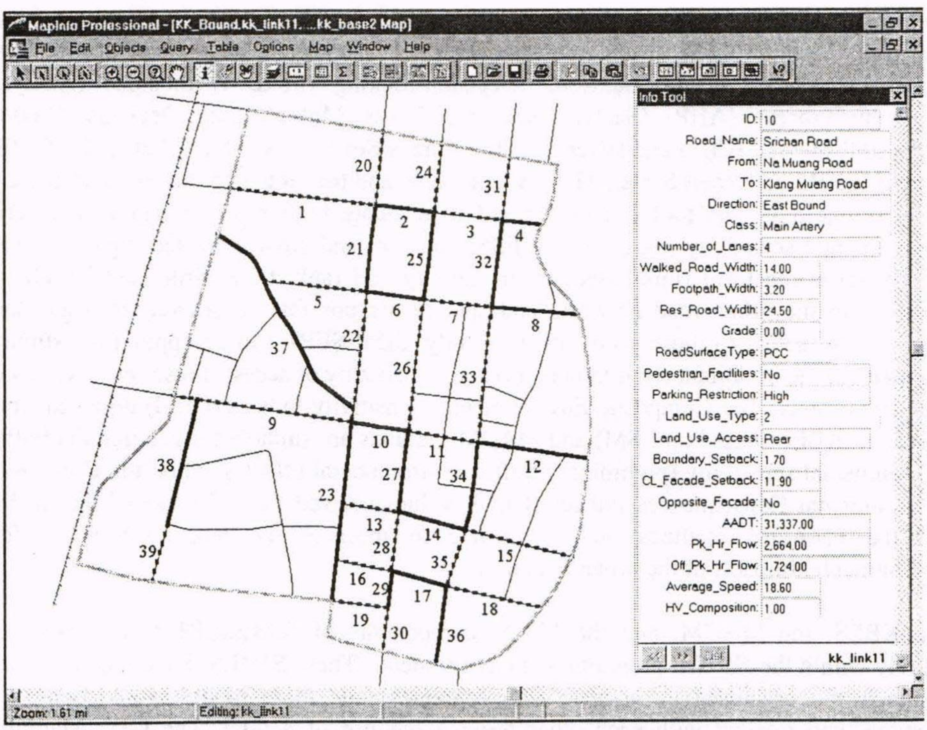

Figure 4. The Khon Kaen CBD road network study area and the attributes associated with each link

NetNoise used a total of 81 links to model the Khon Kaen network. Links were determined using the criteria of avoiding changes of more than 2 dB(A) along an individual link and consistent with that specified in CoRTN (DoT 1988). In general, gradients were considered negligible and all surfaces were classified as Rigid Concrete (the equivalent to Portland Cement Concrete as used in Australia where much research has been conducted into this type of surface) and appropriate prediction corrections applied.

3.2 The Software Packages

Two environmental impact models which were developed by the authors at the Transport Systems Centre were used for these investigations. The models contain GUIs which are designed to be user friendly and intuitive and allow the user to run the programs in the Windows 3.1 (or higher) environment on a PC. This last point is important as it allows the use of the software in areas where an older PC is the only hardware available to the engineer or planner, or where the knowledge of the user has not yet been upgraded to the latest software.

3.2.1 The software Package: SIMESEPT

The *Spatial Intelligent Multicriteria Environmental Sensitivity Evaluation Planning Tool* (SIMESEPT) is a microcomputer-based decision support system. SIMESEPT is an integration of the traffic environmental impacts evaluation methods (Environmental Sensitivity Method (ESM) (Singleton and Twiney, 1985) and the Mathematical Modeling Method (MMM)), the Multiattribute Decision-Making (MADM) methods (Analytic Hierarchy Process (AHP) (Saaty, 1980) and Fuzzy Multiattribute Decision Making (FMADM) method (Chen and Hwang, 1992)), Fuzzy Set Theory (FST) (Zadeh, 1965), the Knowledge-Based Expert System (KBES) approach, and the Graphical Information System (GIS) technology. The tool can be utilised to evaluate both separate and multicriteria environmental sensitivity (based on the ESM concept) and environmental impacts (based on MMM) at the local (link-based) level, identify and rank the environmental problem locations in the urban road network, and specify the possible causes (criteria) and key contributing factors to those problems. Currently, SIMESEPT can be applied to estimate and assess three important environmental criteria: difficulty of access; noise sensitivity, and pedestrian safety. The Composite Environmental Sensitivity Indices (CESI) obtained from the use of KBES (based on ESM) and MADM methods are suitable for gauging the traffic environmental sensitivity (preliminary traffic environmental effects), while the Composite Environmental Consequences Indices (CECI) values derived from the use of the MMM and the FMADM methods are appropriate to measure the more accurate traffic environmental impacts of the urban road network.

The KBES, the MADM, and the MMM components of SIMESEPT were developed entirely within the KPWin programming environment. These SIMESEPT components are designed and organised as separate files (modules) and these modules are connected, operated, and interact with each other through the use of a GUI. The GIS (MapInfo) package was mainly used as the database management system and map-displaying tool. A GUI module was established to manipulate the communication between the GIS and other modules residing within the KPWin environment. In operation, the necessary data contained in GIS can be transferred to other SIMESEPT components by running a specified MapBasic program that extracts the necessary data from MapInfo and then creates its corresponding text file. This text file will then be read directly by the appropriate SIMESEPT files. Subsequently, the outputs derived from those SIMESEPT files will be saved to the specified output file that will subsequently be read to and displayed in the GIS environment. The fundamental structure of SIMESEPT is illustrated in Figure 5 below. The details of each component and the operational procedures of SIMESEPT can be found elsewhere (Klungboonkrong, 1999).

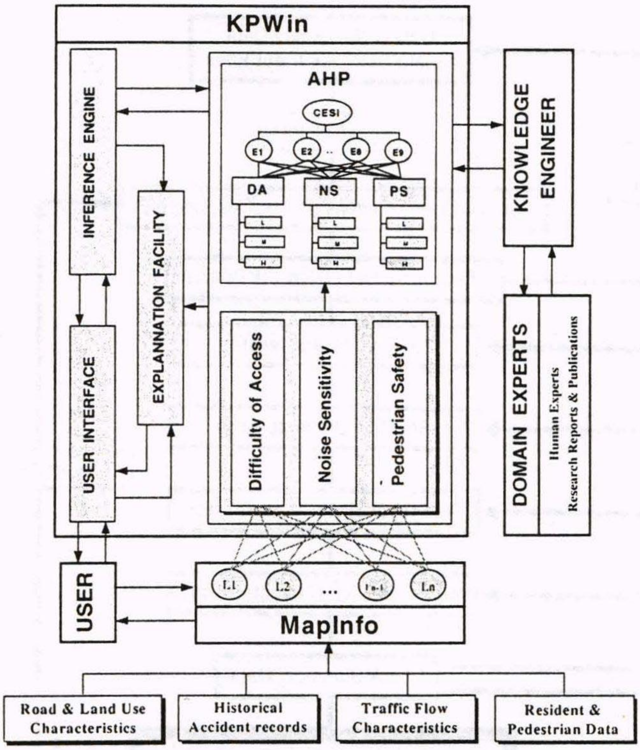

Figure 5 - The basic structure of SIMESEPT

3.2.2 The NetNoise Package

The Network Noise software package (NetNoise) was designed as a highly flexible noise prediction tool with a specific emphasis on predicting noise from road traffic networks. The basic structure and operation of NetNoise is shown in Figure 6 and more detailed descriptions may be found in Woolley and Taylor (1998).

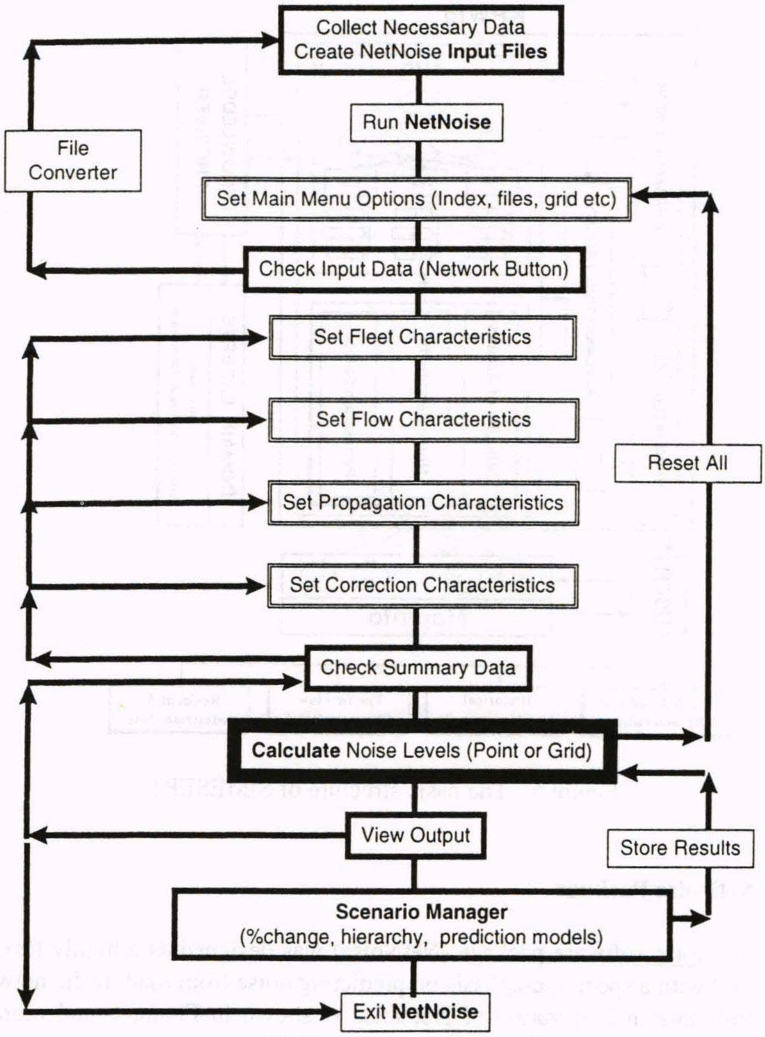

Figure 6: Schematic showing the structure intended use of the NetNoise program

The NetNoise model was used to obtain the distribution of noise from the road traffic network in Khon Kaen. NetNoise uses the Calculation of Road Traffic Noise (CoRTN) procedure developed by the UK Department of Transport (DoT 1988). This procedure has proven to be very robust and has found widespread use around the world and in particular, Commonwealth countries including Australia, New Zealand, Singapore, Hong Kong, South Africa and Canada (Woolley 1997).

Pamanikabud (1990) conducted a study on the Vibhasadee-Rangsit Super-Highway in Bangkok and found CoRTN and the United States Federal Highways Association (FHWA) models to perform as shown in Table 1.

Table 1. Performance of UK CoRTN and US NCHRP models on Bangkok Super-Highway

Noise Prediction Model	Standard error of estimate dB(A)
UK CoRTN (motorcycles as cars)	1.74
UK CoRTN (motorcycles as trucks)	2.92
US FHWA (motorcycles as cars)	3.55
US FHWA (motorcycles as trucks)	1.45

The CoRTN model had a standard error 0.29dB(A) greater than the FHWA model but was deemed suitable for use in the Khon Kaen case study. Since this time both models are due for updates: the FHWA model has now been superseded by the Traffic Noise Model (TNM) and CoRTN is due for its third upgrade to incorporate the Leq noise index and better road surface corrections. The performance and application of these newer models in Asian cities needs to be investigated further.

The CoRTN model performed better when motorcycles were categorised as cars and this modelling scheme was adopted in the Khon Kaen case study. The application of the CoRTN model in the Asian context needs further investigation due to the composition and behaviour of the traffic in urban and non-highway conditions. Like many Asian cities, motorcycles constitute a high proportion of the traffic composition and the treatment of this category of vehicle and its hybrids needs further research in the Asian context. Pamanikabud (1997) has done some work in this regard by modifying the FHWA model to incorporate motorcylces and the tuk-tuk vehicle common throughout Thailand and South East Asia.

One aspect of the NetNoise model is that it allows the user to define whether a vehicle type is categorised as a light or heavy vehicle. Therefore it is a simple matter for motorcycles to be placed in either the light or heavy vehicle category during noise modelling.

Further development in NetNoise

Attempts are being made at present to use the NetNoise model as a training tool for engineers and planners interested in learning about the impacts of road traffic noise in a community. This can largely be achieved by running the model for differing scenarios of the same study area.

The work of Pamanikabud (1997) is also to be implemented into the model so that the user may have the option of the FHWA or CoRTN methods when modelling noise levels. A further study by Pamanikabud (1991) in looking at interrupted traffic flow in Singapore will also be incorporated in addition to other British interrupted flow models.

3.2.3 The Differences between SIMESEPT and NetNoise

SIMESEPT is a microcomputer-based decision support tool that integrate several information technologies (KBES and GIS), management sciences (AHP and FMADM), traffic environmental evaluation methods (ESM and MMM), and FST. SIMESEPT is mainly developed to predict and evaluate the multiple criteria environmental impacts of road traffic at local (link-based) level, identify problem locations, specify the possible causes and key contributing factors to those problems. SIMESEPT can be used to determine three criteria including difficulty of access, noise sensitivity, and pedestrian safety. SIMESEPT is mainly focused on the safety, environmental, and amenity impacts on the residents, pedestrians and people who are live and undertake their activities between the first row of building facades on both sides of each road (as opposed to an area-wide impact appproach). With the structural framework of SIMESEPT, it is relatively easy to add more modules designed to estimate other traffic environmental impacts such as pedestrian delay, air pollution, and others.

While SIMESEPT can be used for initial screening of a network, NetNoise can be used to determine the spatial distribution of noise and rigorously analyse problem locations in more detail than SIMESEPT. NetNoise has the ability to model simple noise barrier configurations and model noise distribution from very coarse to very fine levels of detail. For example, a city may be modelled with noise receivers placed every 100m or every 10m. Areas of the city may be zoomed in with NetNoise and even specific streets investigated with "*what if*" scenarios initiated such as: the banning of heavy vehicles, the changing of speed limits or the altering of traffic volumes.

NetNoise can also be used in an educational context where the user "plays" with the model using its various features to discover the nature of the noise problem being investigated. The GUI of NetNoise easlily allows the user to change conditions and assumptions with the click of a mouse and the Scenario Manager allows the user to think of noise control for the city in broader area-wide terms.

4. MODELLED RESULTS FOR KHON KAEN

SIMESEPT yielded the results as shown in Figures 7 to 10. The figures are presented in terms of difficulty of access, pedestrian safety and noise.

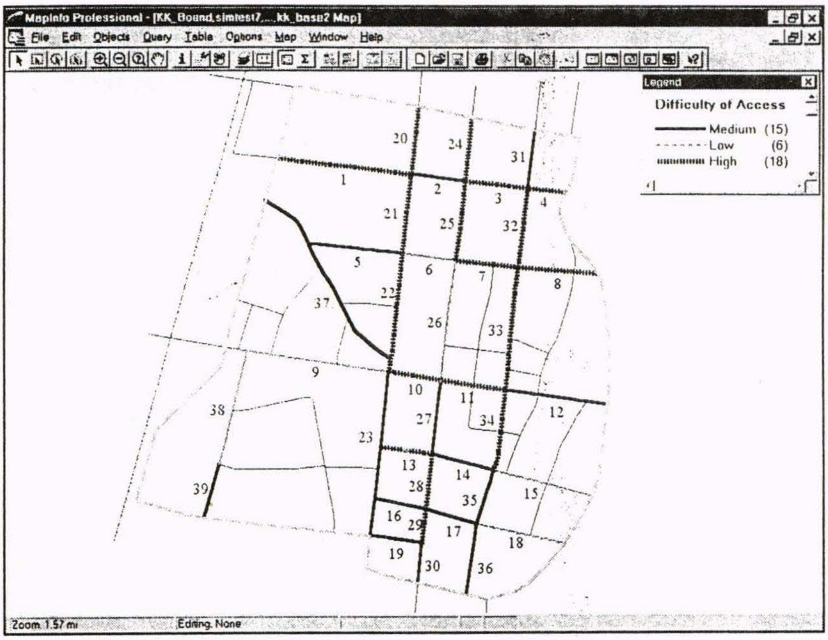

Figure 7. The ES indices of all links in the Khon Kaen road network for difficulty of access

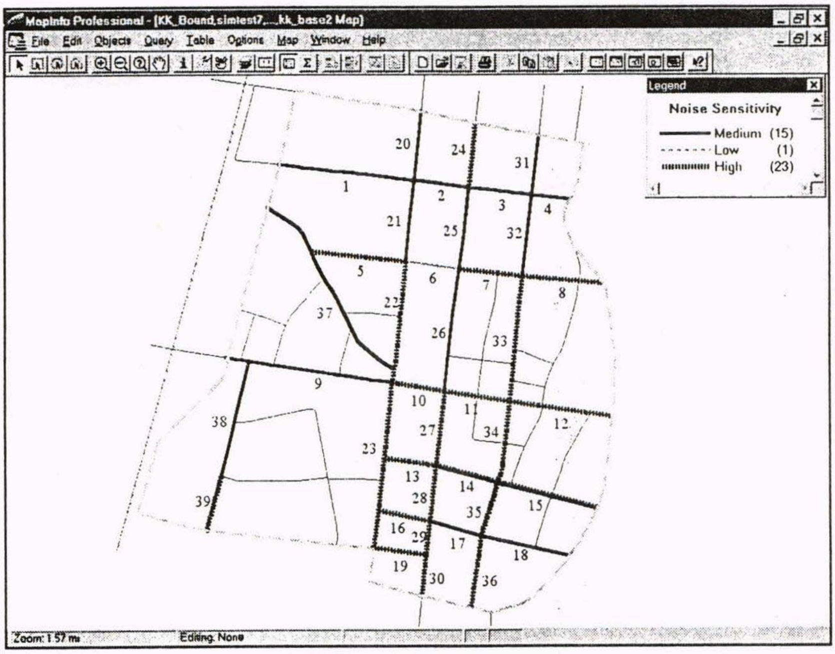

Figure 8. The ES indices of all links in the Khon Kaen road network for noise sensitivity

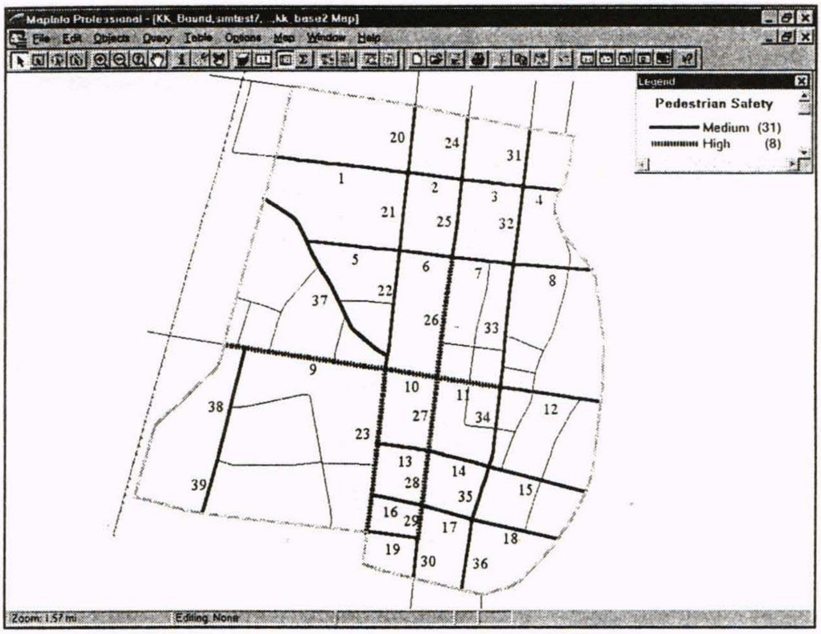

Figure 9. The ES indices of all links in the Khon Kaen road network for pedestrian safety

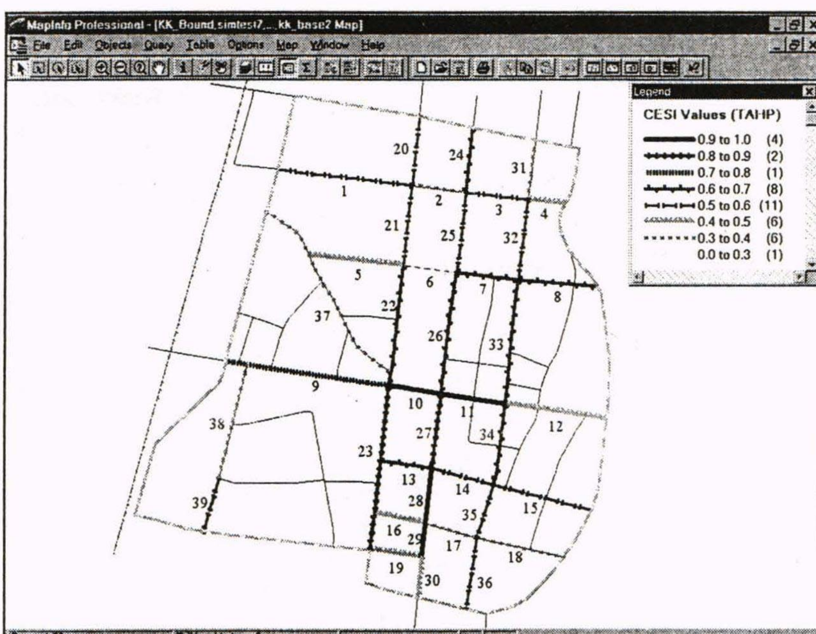

Figure 10. The estimated CESI values of all links in the Khon Kaen road network (based on the TAHP approach)

The spatially distributive patterns of all ES indices of each links for difficulty of access, noise sensitivity, and pedestrian safety are illustrated in Figure 7, Figure 8, and Figure 9, respectively. All links identified as the "High" ES index can be considered as the potential problem sites in the Khon Kaen road network for each of these criteria. For example, link numbers 9, 10, 11, 23, 26, 27, 28, and 29 as shown in Figure 9 are determined as problematic links with respect to the pedestrian safety criterion. Special attention and/or investigation regarding the pedestrian safety aspect may be needed for these links. In addition, SIMESEPT can also provide the user with the rules that were fired to reach the conclusion (the "High" ES index) and the corresponding explanation. For example, at link number 10, the fired rule and its relevant explanation for the achieved "High" ES index for the pedestrian safety is presented below.

Rule:

If ?RoadWidth = Wide
and (?FootpathWidth = Wide or ?FootpathWidth = Narrow)
and (?PedFacility = Yes or ?PedFacility = No)
Then Pedestriansafety = High.

In general, all land use types are highly sensitive to a pedestrian safety criterion when its walked road width is wide.

The key factors contributing to any problematic link for each criterion can be identified from the road physical and land use characteristics data of that link contained in either the input and output text file. For example, for link number 10, the important contributing factors for pedestrian safety can be traced from the input data contained in the specified output text file. In this case, the walked road width as represented by the "RoadWidth" topic is "Wide" (because the number of lanes of this link (four) is greater than two), the footpath width as represented by the "FootpathWidth" topic is "Wide" (because the link's footpath width (3.2 metres) is greater than or equal to three metres), and the availability of pedestrian facilities as represented by the "PedFacility" topic is "No". The similar interpretation is also applicable to other links for each criterion. The estimated CESI values can be used to determine the composite environmental sensitivity of each link for multiple criteria and identify potential problem locations in the urban road network. In addition, these CESI indices can also be utilised to reveal the ranking order of all links according to the magnitudes of their CESI values.

However, link number 10 is adopted to illustrate the numerical computation of the CESI value based on the TAHP method. Link number 10 located in land use type 2 was assigned the "High", "High" and "High" ES indices for difficulty of access, noise sensitivity and pedestrian safety, respectively. The relative weights of difficulty of access, noise sensitivity, and pedestrian safety for land use type 2 are 0.2856, 0.1067, and 0.6078, respectively. The normalised relative weight of the "High" ES index for each of these three criteria is identical (1.000). Based on the principle of hierarchic composition, the estimated CESI value of link number 10 is 1.000 (= {0.2856*1.000}*{0.1067*1.000}*{0.6078*1.000}). All CESI values estimated for all links in the Khon Kaen road network were grouped into eight intervals and displayed in Figure 11.

The CESI values of seven links (link numbers: 9, 10, 11, 23, 27, 28, and 29) are high (greater than 0.7000) and therefore identify the potential problem locations. According to the output data contained in the output file, the rank of these links according to the magnitudes of their CESI values in descending order are: link numbers 10, 11, 28, and 29 (CESI = 1.000), link numbers 23 and 27 (0.840), and link number 9 (0.700). In addition, the numerical composition of CESI values can also be used to determine the potential causes of the problems for each link. For example, for link number 10, the descending rank of likely causes (criteria) of the environmental problem on this link are: pedestrian safety (0.608 = (0.6078*1.000)); difficulty of access (0.286= (0.2856*1.000)); and noise sensitivity (0.107= (0.1067*1.000)), respectively.

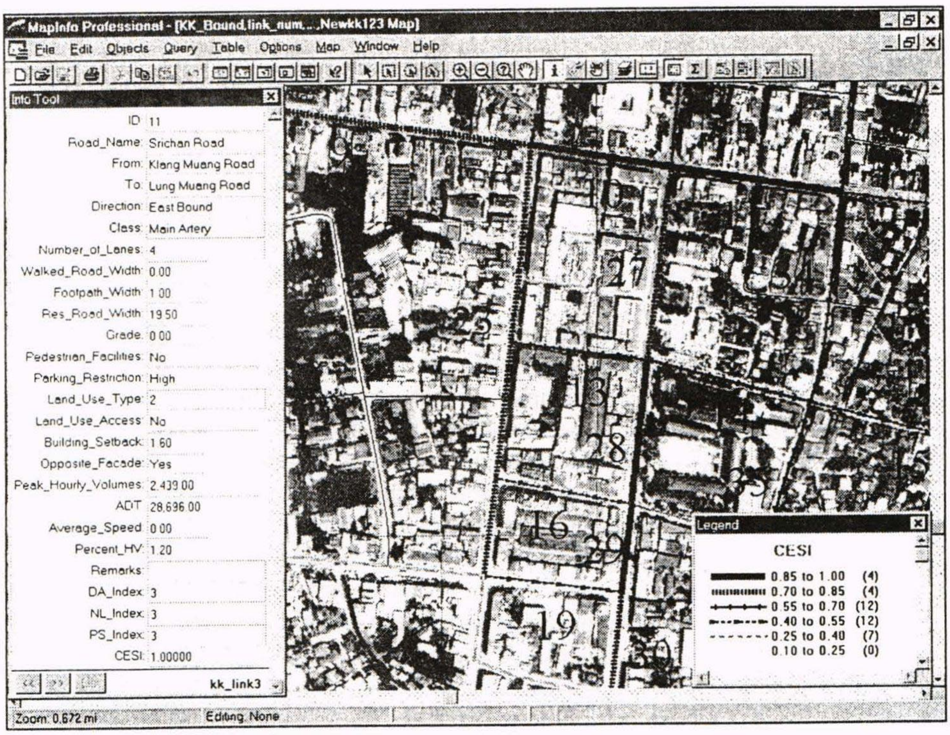

Figure 11. Example of details for the CESI contained in the MapInfo GIS for link 11

3.4 NetNoise Output

As mentioned previously, noise modelling was conducted with motorcycles being included in the light (or passenger vehicle) category. The road surface type in Khon Kaen is predominantly rigid concrete and the NetNoise correction of +1.0dB(A) (relative to the conventional flexible Densely Graded Aspaltic Concrete pavement) was applied throughout. All the roads in the network were considered to possess negligible or zero gradient. The amount of absorbent ground for the network was considered negligible in the immediate vacinity of road ways due to footpaths and the built form. A facade correction of +2.5 dB(A) was incorporated due to the extensive presence of the built form in the area. This essentially allows for the estimation of noise levels 1m in front of a building facade.

Modelling results show that very high noise levels exist in the vacinity of the heavily trafficked roads. According to OECD guidelines of Black and Grey Areas (OECD 1986), much of the Khon Kaen study area may be considered to not be meeting the OECD criteria as shown in Figure 12. The problem is a difficult one to solve as the main culprit is the large volume of traffic in close proximity to the adjacent land uses within the CBD. The lowering of speeds or the banning of heavy vehicles would have minimal effect in this case as these variables are already quite small. A short term solution may be to redistribute the traffic around the CBD but this is essentially relieving the problem in the CBD but redistributing the problem to other areas.

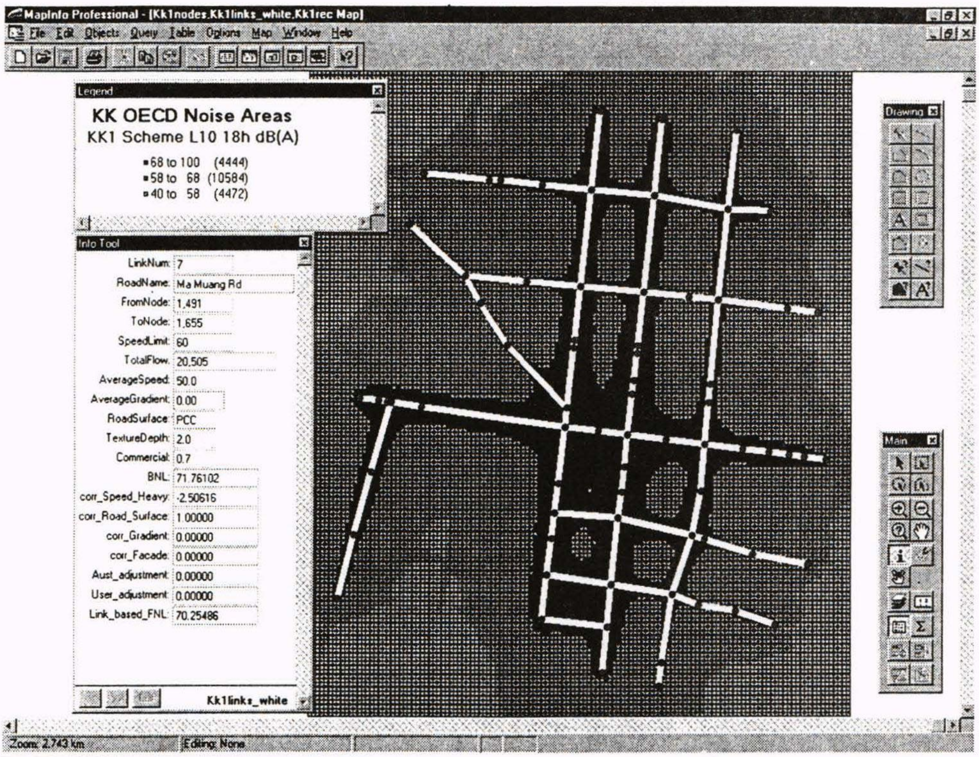

Figure 12. Noise distribution over the Khon Kaen CBD showing OECD limits in the MapInfo GIS environment (adjusted for L_{10} 18h dB(A))

4. FURTHER WORK

Further research work is being planned in order to validate the model predictions including a series of noise measurements in the Khon Kaen city. Whilst an area-wide calibration of NetNoise is nearly an impossible task over the entire Khon Kaen CBD, point calibrations may be performed at strategic locations around the city.

The effect of the built environment in providing buffering for noise needs to be investigated and various scenarios planned in order to better manage the large volumes of traffic in the CBD area.

The use of Pamanikabud's models and their implementation into NetNoise is seen as an essential next step in the adaptation of a model for developing Asian cities. SIMESEPT has already incorporated Thai experts into its models and may be further expanded to incorporate issues such as air pollution into its environmental repertoire.

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