

Multi-level geographical information and expert systems for comprehensive evaluation of urban transportation policies

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Abstract

The growing awareness among urban dwellers about environmental deterioration which mainly occurs from transportation sources demand careful consideration of the various policies in urban transportation planning for improving the environment.

This paper presents an integrated approach implemented in a computer aided system for the practical application of comprehensive EIA in urban transportation planning. The Computer Aided Landuse Transport Environment Analysis System (CALTEAS) consists of a multi-level GIS based data base and three other major sub systems - Simulation, Evaluation and Map Display. Finally, the possibilities of practical application of the system in urban transportation planning are demonstrated through some examples.

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INTRODUCTION

Environmental Issues in Urban Transportation Planning

The growing awareness among the urban dwellers about the deteriorating environment has resulted in a variety of legislative measures to preserve the environmental quality. One of the major causes of environmental deterioration is urban transportation, because it not only directly but also indirectly affects the environment. Transportation sources make up a large percentage of environmental pollution generated by human activities in the urban areas. In Japan, on a national basis about 90% of all CO emissions, and a less proportion of NO_x come from the transport sector, and mainly from road traffic. More than 30% of total population in Japan are exposed to noise levels in excess of 65 dB(A) from road traffic noise alone (JEA, 1989). Land consumption by transport infrastructures may result in loss of green spaces or conflict with other land uses and also influence access and property values. Accident risks, consumption of energy resources and solid waste problems are some of the other major consequences of transport. Such impacts depend very much on the production, operation and maintenance of transport infrastructure, and the different modes (for example, air, rail, road) and technologies used. Then, in the planning and implementation of improvements in urban transportation, it is essential to carefully consider the conservation of environmental quality against the other economic benefits. Also, it is not sufficient just to consider posterior measures for environmental improvement or alleviate environmental problems temporarily through short term measures. Some of the environmental damages have gone beyond remedies that the posterior approach, to "wait and see", could be very disastrous (WCED, 1987). The comprehensive analysis of policies should evaluate their economic feasibility, social impacts and more importantly the environmental improvement, right from the higher levels in the planning with a long term perspective. This paper focuses on a comprehensive review and close understanding of the planning process, the role of environment in the urban activities and the potentials of the existing methodologies for one aspect, namely the environmental, in the analysis of the policies.

Problems with the Existing Approaches for EIA

Existing approaches for Environmental Impact Assessment (EIA) (reviewed in Seetharam et al., 1988) offer only a piece meal or relatively posterior solution to the problems and do not address the following issues involved in the comprehensive EIA in urban transportation planning:

(i) Multi-level aspects in urban transportation planning: In any urban region, the transportation planning and design are carried out at a number of levels of detail and decision making. The analyses and decisions change from one level to another level of the planning. Also, the urban transportation planning is not a unique task but a set of sub tasks of different scales and scopes. Table 1 shows a summary of the different analyses and decisions required at the different levels of planning. For example, at the detailed design level, the estimation of noise and air pollution from road traffic requires a microscopic view of transportation system. But the analysis of changes in the land use as a result of a new master plan must be done, at a much macroscopic level, with estimates made over a longer period.

Table 1 LEVELS IN URBAN TRANSPORTATION PLANNING

	MASTER PLAN	PROJECT PLAN	DETAILED DESIGN
Plans for	Urban Scale	Local Scale	Design and Implementation
Plan Contents	Network design New Transport modes	Traffic control over a large area	Road design signal control, Anti-noise wall
Plan Period	20 Years	10 Years	Based on Proposal
Map scale	1:100000 or less	1:10000 ~ 25000	1:1000 ~ 2500
Locational data	Zones	Street blocks	Individual buildings
Road data	location of major trunk roads	location and structure of minor trunk roads	location and detailed structure of all roads
Traffic data	daily volume, etc.	daily volume by mode, etc.	possible hourly volume by mode, etc.
Forecast	Changes in population, Employment, Landuse & Travel demand Total emission of pollutants in the area	Changes in Travel pattern, Road traffic Population exposed to pollutants in the area	Hourly variation of traffic by mode Level of pollutants near the buildings

Present approaches for EIA in urban transportation planning deal with mainly the detailed design level, where only the direct environmental impacts such as noise and air pollution from road traffic are considered. The policies that can be tested at this level are limited in number and effectivity.

Actually, while the levels are distinctly separated by many criteria, there is also much interaction among the levels, at all stages, before, after and during each sub task, in the entire master plan cycle being implemented. While the project decisions flow top-down, the posterior impacts flow bottom-up between the levels.

To support the aforementioned multi-level process in the urban transportation planning and the interaction among the levels, there is much need for a multi-level data base management. A unified data structure will be desirable to rationally maintain the information for all the levels and also support the links among the levels.

(ii) Modeling approaches based on Landuse-Transport-Environment interaction: The understanding and analyses of the interaction among the Landuse, Transport and Environment as shown in Figure 1 are very important to effectively evaluate the impacts of improvements in urban transportation. Existing studies have considered the landuse and Transport interaction in detail and explicitly (ISGLUTI, 1988). The deficiencies in the existing approaches is that they lay a larger emphasis on the Landuse-Transport interaction, which is behavioral, leaving the environmental impacts as externalities and treating the

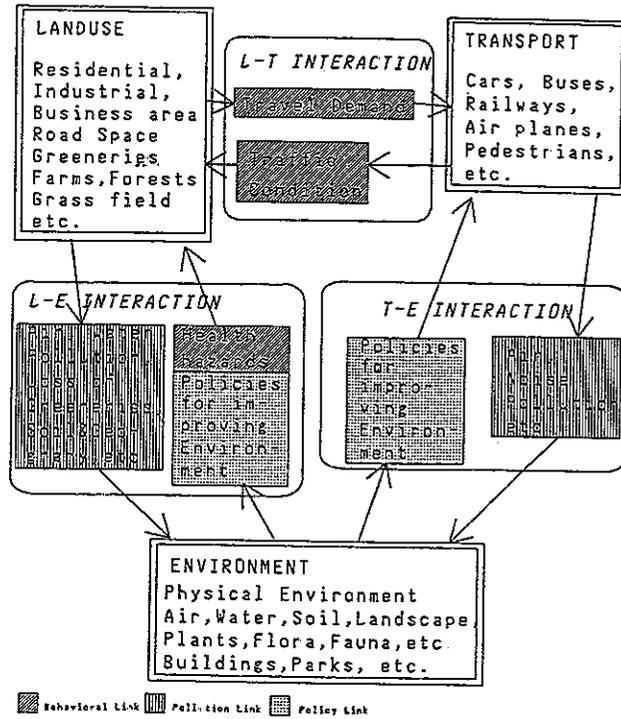


Figure 1 ENVIRONMENT-LANDUSE-TRANSPORT INTERACTION

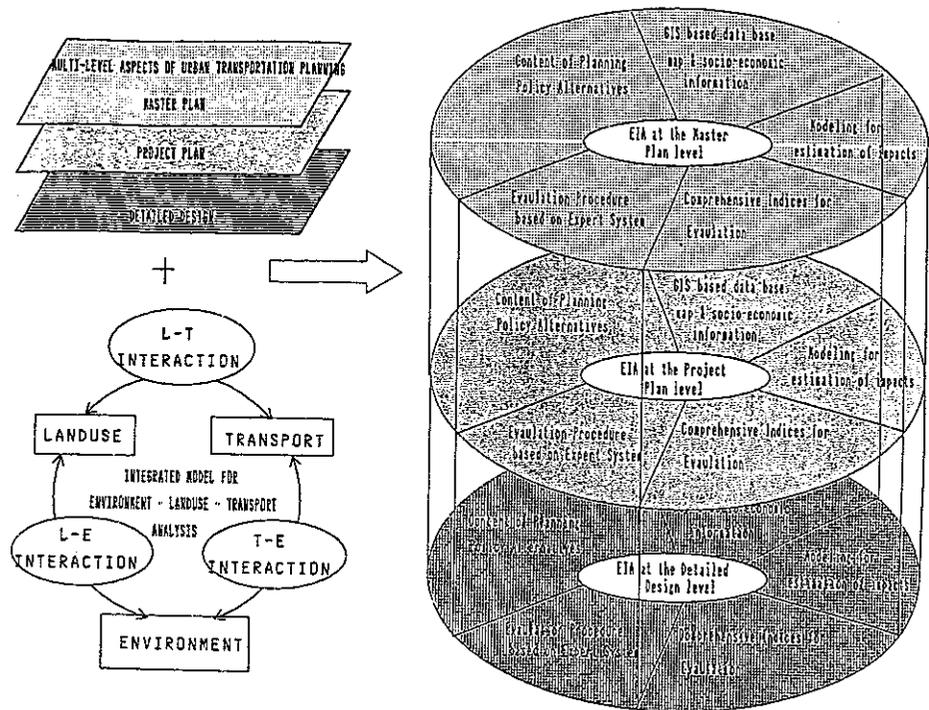


Figure 2 OVERALL CONCEPT OF THE INTEGRATED EIA & CALTEAS

policy variables exogenous. The current approach shows a new direction to overcome these deficiencies by explicitly considering the non-behavioral, pollution and policy links in the Transport-Environment and Landuse-Environment interactions, thus satisfactorily representing the urban changes (Seetharam et.al., 1989). Further, much of the wide variety of impacts cannot be estimated with conventional models since either sufficient quantitative information is not readily available to calibrate them or the available qualitative information cannot be easily assimilated by them.

(iii) Comprehensive evaluation procedure: The existing evaluation processes do not clearly represent the links between the estimated values of the environmental indices such as noise and air pollution, the overall impacts on the quality of life of the affected population and the decision making process in the planning.

The existing EIA approaches also do not identify satisfactorily the different types of uncertainties in the planning process arising from (a) the ambiguities at the higher levels in the policy variables, for example, with a ring road plan - its location, capacity, etc., (b) the unreliability of the data for calibrating a quantitative model used in the estimation, and (c) the diverse priorities and opinions among the affected groups and decision-makers about the various impacts of a policy. These uncertainties comprehensively affect the policy decision.

AN INTEGRATED APPROACH FOR COMPREHENSIVE EVALUATION OF URBAN TRANSPORTATION POLICIES

Overall Concept of the Integrated Approach for EIA

An integrated approach is proposed here for the comprehensive EIA of urban transportation policies. The new approach shown in Figure 2 aims to consider both the multi-level aspects of the urban transportation planning process and the interaction among Landuse, Transport and Environment. The capabilities of the new approach can be listed as follows:

- a) support the multi-level data management, that is, data of different details and volumes, required in the EIA,
- b) support the macro & microscopic analyses required in the EIA,
- c) support the estimation of both long and short term impacts on a variety of indicators,
- d) efficiently consider insufficiency of quantitative information and compromise with the available qualitative information, and
- e) incorporate public and expert opinions to evaluate policies from the viewpoint of different groups of the affected population.

With the integrated EIA it will be possible to meet the typical requirements for environmental analysis of urban transportation policies which can be classified based on the levels of planning

Policies for Improving the Environment

The policies aimed at improving the transport environment are directed towards either:

(i) reducing the traffic congestion by

- a) trip generation control - traffic demand arises from generation-attraction characteristics of particular areas in a wide region. The demand is mainly characterized by the population, employment

opportunities and other commercial and educational facilities in that area, and most of all the levels transportation services available there. For example, the demand for road traffic will reduce when a rail based mass transit is introduced in the central area.

b) network management and road space usage improvement - a wide variety of Transport System Management Strategies fall in this category. Although their application is generally limited to small areas, their efficiency is good especially to redistribute existing capacities to meet temporal changes in traffic demand. For example, during the peak hours, certain main roads are provided with bus lanes for better public transport speeds. Nevertheless, network management can only manage demands that are below the actual capacity of the network itself.

or (ii) reducing the severity of impact by

a) dampers for impact - a very efficient posterior approach to the noise pollution in a localized area on the side of major trunk roads or expressways is the construction of dampers, like noise walls. Trees also help to some extent in the alleviation of air pollution.

b) road side land use control - instead of controlling the source of pollution, another school of thought suggests the removal of affected groups from the imminent zone.

The Policies can be classified based on several criteria as shown in Figure 3 such as, a) the area of impact - wide area, local area, b) the policy nature - infrastructural investment, legal measure, operational management, economic measure, c) time scale - long term, transient, immediate and d) flexibility - reversible, irreversible, among others. Generally at the higher levels the policies may be investment burdening aiming for a long term environmental improvement over a wide area, while at the lower levels immediate measures for providing a local and temporary relief from environmental impacts are chosen, as shown in Figure 3. Such classification and understanding of the policies enhance the choice of appropriate policies for particular problems.

COMPUTER AIDED LANDUSE TRANSPORT ENVIRONMENT ANALYSIS SYSTEM (CALTEAS)

Main Features of the Computer System

The computer aided system developed by the authors is called Computer Aided Landuse Transport Environment Analysis System (CALTEAS). It consists of a Multi-level GIS based database and several user-interactive modules for performing input, display, analysis and evaluation which are essential for the integrated EIA. These modules can be classified into three sub systems, namely simulation, evaluation and map display. There are several commands which can be selected interactively with the mouse on the color displays. CALTEAS has been developed on Sun workstations (Sun Micro Systems Corporation).

THE MULTI-LEVEL GEOGRAPHICAL INFORMATION SYSTEM

Conventional GIS & its application in CALTEAS

To efficiently handle a variety of spatial information in an organized manner, a Geographical Information System (GIS) is indispensable. The GIS supports various types of spatial queries which are required in the

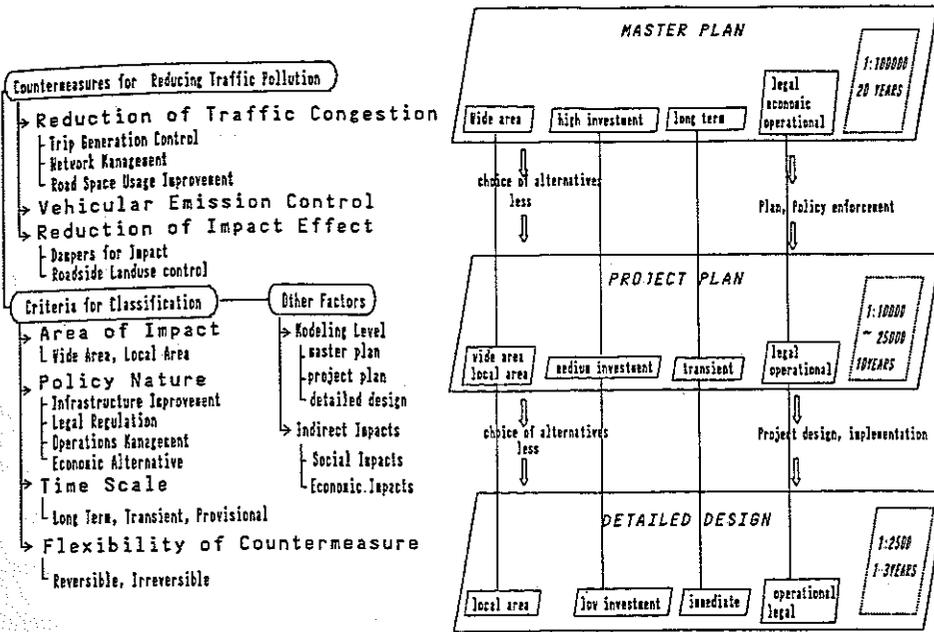


Figure 3 URBAN TRANSPORTATION POLICIES FOR IMPROVING THE ENVIRONMENT

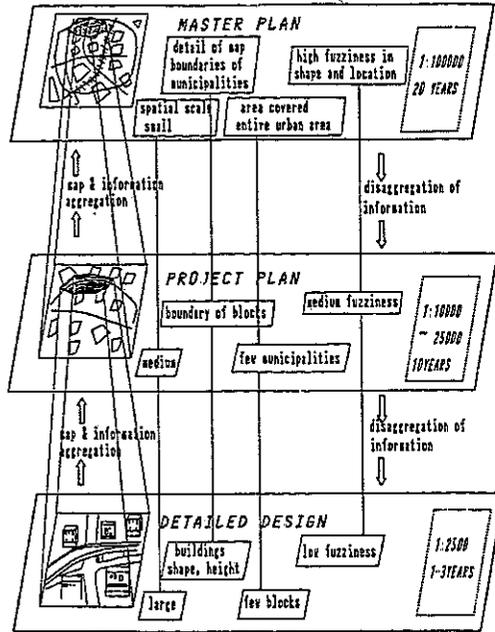


Figure 4 MULTI-LEVEL DATA MANAGEMENT FOR THE INTEGRATED EIA

different analyses. For example, the distance from a building to the nearest road can be automatically estimated, to be used to forecast the noise levels or so on. A GIS can maintain different types spatial informations as layers. The topology representing the points, lines and polygons sufficiently represents all two dimensional map features on a vector image. Raster images such as grids can be also stored in the GIS. Then for the same map - population, landuse, etc. can be stored as attributes of the features in the vector or raster images.

The multi-level planning process supported by the integrated EIA requires a multi-level data management as summarized in Figure 4 and highlighted as follows:

- a) Map data with different geometric accuracies, uncertainties and details are required simultaneously in the Integrated EIA.
- b) Maps at different levels must be matched geometrically.
- c) Socio-economic, landuse, traffic and environmental data available with these maps must be linked correspondingly.
- d) These data must be automatically aggregated and disaggregated for the different estimations in the integrated EIA.

Conventional GIS approaches cannot efficiently address all of these requirements. The problems can be summarized as follows:

- a) Basically several layers of maps with varying details must be created. This increases data volume and redundancy.
- b) Maps and other socio-economic data that are created separately for each level cannot be linked very easily.
- c) The approaches for multi-level analyses concentrate on the procedure for aggregating and disaggregating socio-economic and other attribute information across different levels by relating them separately, usually coding, etc. Such procedures are manual, laborious and their errors cannot be detected, if the spatial reality of the cross references is not expressed.
- d) Geometric uncertainties at the higher levels cannot be considered in the data structure.

Advantages of the Multi-level GIS

CALTEAS consists of a multi-level GIS database sub system based on ARC/INFO, commercially available from the Environmental Systems Research Institute, U.S.A. The multi-level GIS can assimilate map and attribute information of different scales and geometric uncertainties, supporting complicated spatial queries required in the analysis. Its advantages can be quickly summarized as follows:

- a) Map data with different geometric details and uncertainties are created as are required in the application.
- b) The redundancy in data reduced considerably.
- c) Spatial correspondence is established using buffering and other matching techniques for developing links between the maps.
- d) Maps for higher levels can be automatically created by geometric aggregation techniques.
- e) Simultaneously maps are available at different levels.
- f) Errors in links between the maps at different levels can be detected and edited interactively on the display.
- g) Socio-economic and landuse data and traffic assignment results available at one level can be automatically aggregated or disaggregated to other levels.

This facilitates the distributed development of GIS for an area without the redundancy of information. For example, to analyze the environmental impacts at the detailed design level in a small area, first

the lower level GIS based on a detailed large scale map is developed. Then, in order to comprehensively analyze various policies at higher levels, the GIS based on a small scale map for a larger area will be necessary, in which case, only the rest of the area not represented in the lower level GIS will have to be digitized from the beginning. Automatically, the features already included in the lower level GIS can be aggregated to generate the corresponding features for the higher level GIS. Further, the estimations made at the higher levels can be disaggregated to the lower level GIS for further analyses at the detailed design level, thus integrating the overall decision process.

Data Structure and Special Functions

Data Structure: The data required for the analyses are obtained at different scales and details corresponding to the levels of planning. So, the data structure of the multi-level GIS has additional information, other than those required for representing topological relationships in a conventional GIS for the elements (point, line, polygon). For example, the boundaries of municipalities are digitized at the master plan level, whereas at the project plan level, the boundary of large blocks, and the shape of each lot at the detailed design level.

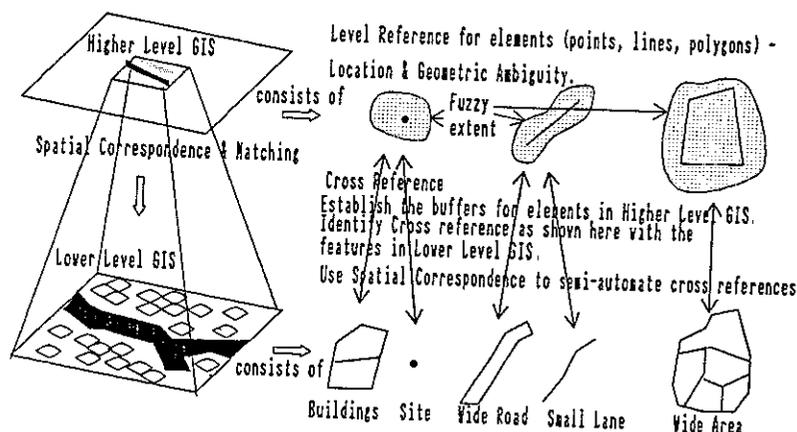
First, the level at which each piece of boundary information was originally input is identified along with its geometric ambiguity through a fuzzy function. This concept is called the Level Reference. So, using this information we can generate the buffers representing the possible spatial extent of each feature as shown in Figure 5.

Then, a Cross Reference is required for each information to identify corresponding elements at the other levels, for example, the lot digitized at the detailed design level belongs to some block at the project plan level and a municipality at the master plan level, to aggregate and disaggregate the attribute informations. As shown in Figure 5, a point in higher level may correspond to a set of points, or polygons at the lower level, and so on. The cross reference links both the geometric as well as attribute information of the corresponded features. For example, if a point at the higher level represents set of buildings at the lower level, the population attribute for the point will be the sum of all the populations in the buildings it represents.

Some of the typical approaches for establishing the level reference cross reference and attribute aggregation (Seetharam, et.al.1990) are based on: i)official designation of the area - for example, the buildings in a municipality are represented as individual features at the lowest level, while at the next level, they may be aggregated into several blocks they belong to and may be the entire municipality is represented by one area feature at the highest level, ii)requirements in the modeling & iii)the map resolution. The cross references for the classifications based on official designation or modeling can be manually coded which is prevalent in the conventional GIS, although it is a very laborious task

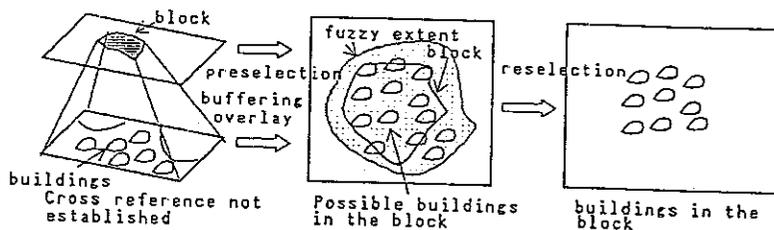
Special Functions of Multi-level GIS: The semi-automation of cross references between elements in two levels is possible by identifying the spatial correspondence between the two levels. For example, with area features representing the buildings at the lower level and at the higher level, the boundary of the block represented by an area feature, first a buffer is generated representing the probable extent of the block considering geometric ambiguity in its location. By overlaying the maps at the two levels, the possible buildings belonging to the block can be

a) LEVEL REFERENCE & CROSS REFERENCE

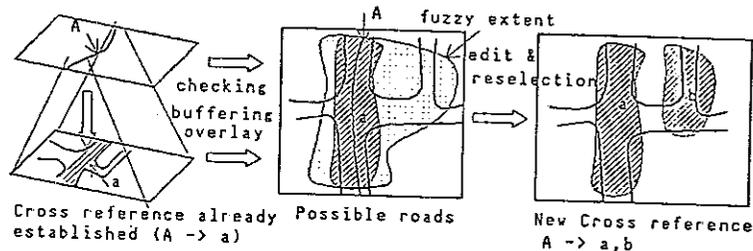


b) SEMI-AUTOMATION OF CROSS REFERENCES, EDIT & QUERY

e.g: Establishing cross references for block - buildings



e.g: Editing cross references for Roads



e.g: General Spatial Query

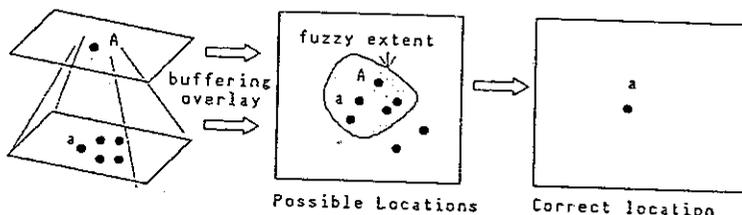


Figure 5 FEATURES OF THE MULTI-LEVEL GIS IN CALTEAS

pre-selected automatically using a "polygon-in-polygon analysis" and displayed. Finally, from this selection, the desired buildings can be reselected interactively to represent the cross reference as shown in Figure 5. Such a pre-selection, interactive edit and reselection enhances the process of developing cross references very much. With this function, cross references developed manually elsewhere can be displayed and their errors can be edited, if any. The same feature can be used for spatial query, such as the location in the lower level of a point belonging to the higher level. It is also possible to represent the spatial relationship in a qualitative manner considering the geometric ambiguities in the features and to automatically generate features at higher levels applying boundary aggregation in the lower level GIS.

FUZZY MODELS AND EXPERT SYSTEM

Fuzzy Modeling in the Simulation Subsystem

The Simulation sub system is based on a model for analyzing the impacts of policies considering the interaction among Landuse, Transport and Environment. The importance of each link between I-U-T-E in the modeling with respect to the level of planning and the policy evaluated have been discussed in detail earlier (Seetharam, 1989). The main feature of the simulation sub system discussed here is the incorporation of fuzzy models for qualitatively estimating the traffic situation, environmental and other indirect impacts.

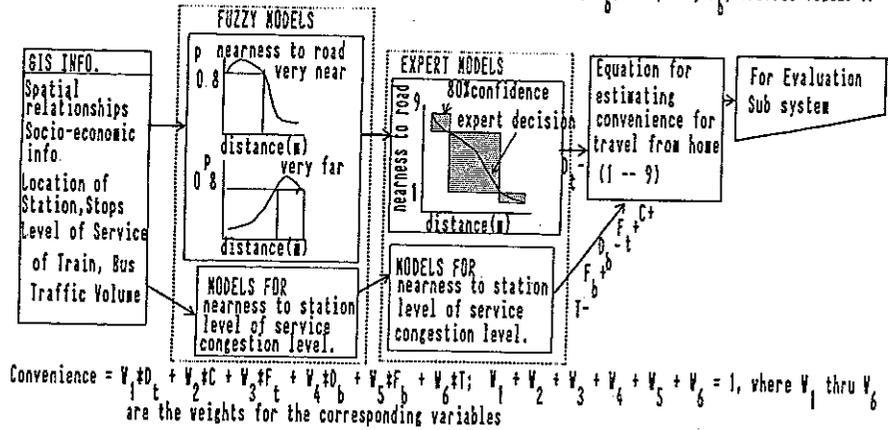
Usually, a wide variety of estimates are required in the integrated EIA, like "convenience for travel", which cannot be estimated with quantitative models and can be represented only on a simple scale like "good(say 9)-bad(say 1)". In actual applications, there may not be sufficient statistically consistent quantitative information readily available to calibrate quantitative models for reliable estimations. Using fuzzy inferences each affecting parameter can be qualitatively described, for example, "the nearness road" as "very near(say 9), very far(say 1)". Then an expert model can be interactively defined from probable choices, say 80%, to represent each part of the index, convenience for travel based on nearness to road vs. actual distance, and the impact on the index can be evaluated as shown in Figure 6.

In another situation, statistically reliable quantitative estimates may not be available, for example, "the traffic volume" to evaluate the impacts of a traffic ban on a quantitative index like "noise pollution". Again, using fuzzy inferences the changes in traffic volume can be obtained from experts in a qualitative manner. Such models can serve as posterior or anterior processors, as shown in Figure 6, in the estimation of noise pollution qualitatively. The qualitative estimates in both cases are valuable in the evaluation process.

Expert System in the Evaluation Subsystem

The Evaluation sub system of CALTEAS consists of an expert system for evaluating the policies and decision analysis using comprehensive indices developed with fuzzy inferences. The capability of the system, to interactively select the policies and evaluation criteria and present the results of EIA through easily understandable visuals, is very important for the communication among the planner, the decision maker

QUALITATIVE INDEX: e.g.: Convenience for Travel = f(Nearness to Station D_t , Capacity of Rail C , Frequency F_t , (1-very bad, 9-very good) nearness to bus stop D_b , frequency F_b , Traffic Volume T)



QUANTITATIVE INDEX: e.g.: Noise pollution near buildings after a traffic ban

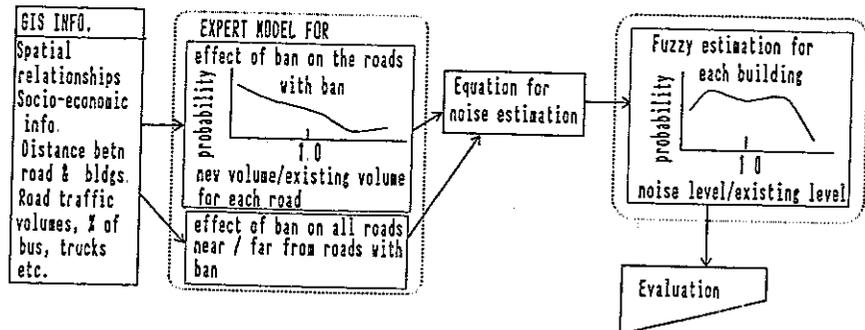


Figure 6 FUZZY MODELING IN THE SIMULATION SUB SYSTEM IN CALTEAS

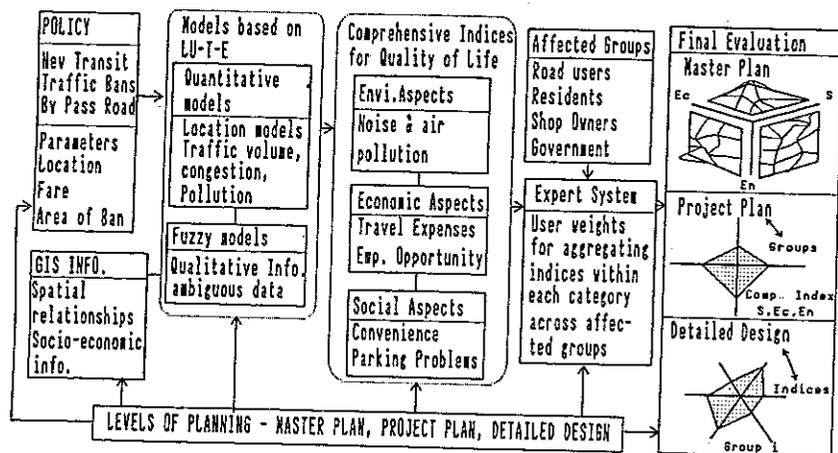


Figure 7 EXPERT SYSTEM IN THE EVALUATION SUB SYSTEM

and the concerned groups. The overall framework for the expert system approach in CALTEAS is shown in Figure 7.

Comprehensive indices incorporating quantitative & qualitative impacts using fuzzy models: To comprehensively evaluate the policies it is important to consider their impacts on a wide variety of indices representing the "Quality of Life" that fall into three broad categories:

- a) Bio-physical Environmental Aspects - Noise & air pollution, Garbage disposal/collection, Waste water collection, Greenery;
- b) Social Aspects - Accidents, Emergency Services(Ambulance, Fire Fighting Service, Natural Disaster), Security Services(Crimes), Accessibility, Educational Facilities, Shopping Facilities, Medical Facilities, Open Space(Parks & play ground), Landscape, Townscape;
- c) Economic Aspects - Daily Household Expenses, Land Price, House rent, Travel Expenses, Income level, National Health Services, National Pension Services, Employment Opportunities, Local Tax.

The impacts are evaluated variably by each person in the affected population fall into four main groups:

- a) Road / Transport Users - Office Commuters, Students, Shoppers, Vehicle Drivers, Aged & Handicapped Persons, Children;
- b) Residents (near Roads, Railway lines, stations, etc.) - Land Owners, Renters, Aged & Sick Persons, Children;
- c) Shop Owners (near Roads, Railway lines, stations, etc.) affected by the indirect economic impacts;
- d) Transport Operators - Government, Public, Private.

The types of impacts to be considered and the statistical nature of the indices to representing them for evaluation vary with the level of planning. Generally at lower levels the detailed spatial distribution of the actual values of the indices representing the direct impacts will suffice, while at higher levels the indirect impacts will also have to be considered and the long term trends for the statistically representative values of the indices over a large area will be necessary.

The fuzziness in the spatial information and the uncertainties in the estimation very much affect the evaluation and decision-making process. To aggregate impacts of the different types of indices, quantitative and qualitative, also considering the fuzziness in the estimation, the severity of impact on each index is represented on a non-dimensional scale using an expert model. For example, the noise pollution estimated in dB(A) in the area is shown on a simple scale 1 through 9, where 9 represents very good support for the policy corresponding to noise level, probably, 20 db(A). A value 1 represents no support for the policy corresponding to a noise level, probably 90 db(A), meaning that from an environmental viewpoint the amenity is bad. The expert model for each index depends on the affected group (residents, shop owners, etc.) in the area. Now, the "severities" for the indices can be aggregated for one affected group over the area to yield the distribution of population of that group exposed to different levels of severity 1 through 9 for each index.

Evaluation of policies: The objective of the final evaluation is to present graphical displays of the overall impact of the policies than some numerical values. The decision maker can interpret the results and make the final decision. The final evaluation procedure uses the results of the aggregation of impacts. The aggregation of impacts yield the distribution of population in each group for the different levels of "severity" for each index. The final evaluation process considers two issues. The priorities of a group, say residents, for two indices E_1 and

E_2 in the same category, say bio-physical environmental aspect, are different. Thus, total impacts of a level 1 on E_1 and 9 on E_2 is not necessarily the same as 9 on E_1 and 1 on E_2 . Next, these priorities again vary with another affected group. So for example, level 1 on E_1 and 9 on E_2 is evaluated differently by residents and shop owners. Finally, the indices across categories are not compared since they basically represent different aspects of the quality of life.

At the detailed design level, the comprehensive evaluation for each alternative can be performed by inspecting the average and peak level of severity for each index, for each population group as shown in Figure 7. Then, the desired policy can be selected by the decision maker from the evaluation of the situations before and after each policy.

At the project plan level, the relative priorities for the indices in each category obtained by community participation or expert knowledges is used to develop the distribution of impact for each level of comprehensive index in each category. For example, if the weights of bio-physical environmental indices (E_1 .. E_n) for residents are W_{1g} .. W_{ng} respectively, then the comprehensive index can be calculated as follows for each level of severity (i), the number of residents exposed, $E_{Gi} = W_{1g} * P_{1gi} + \dots + W_{ng} * P_{ngi}$, where P_{1gi} represents number of residents exposed to level i of severity to index 1 and so on. Then, the average or peak level of severity for each comprehensive index for each population group can be displayed as shown in Figure 7. The decision can be made from the graphs showing the trends for a few years with and without each policy.

Finally at the master plan level, the weights for the opinion of different groups (residents, W_G , etc.) are decided by the decision maker or expert, and used in the further aggregation of the impacts across the population groups to estimate comprehensive values for all the levels of severity in each category such as, $E_i = E_{Gi} * W_G + E_{pi} * W_{pi} \dots$, as shown in Figure 7. Then, long term trends of these values for each policy can be used in the decision making. All these weights can be modified interactively in CALTEAS.

APPLICATION

In order to demonstrate the capabilities of the multi-level GIS and the expert system in CALTEAS a case study was attempted to analyze the impacts of a policy for banning trucks on selected roads in the Tokyo Metropolitan Area and evaluate at the master plan level. A wide variety of data was assimilated into the Multi-level GIS as listed in Table 2. Then, to develop the GIS for the analysis the following steps were necessary:

- 1) The population, other data based on the municipalities for the Tokyo metropolitan area were extracted from the GIS for the whole Kanto area.
- 2) The Kanto area road network was used for the 4-step traffic assignment, to estimate the traffic volumes with and without ban on truck on selected roads.
- 3) The 100m mesh based landuse data was aggregated to 500m mesh.
- 4) The noise and air pollution (NO_x) from the road traffic were estimated based on the 500m mesh.
- 5) Then using spatial correspondence and cross-reference, the socio-economic data in 1) for the case study area was disaggregated to the GIS in 3).

Table 2 Summary of Data base information on Tokyo Metropolitan Area

Classification of the Data	Details of the Data (area, etc.)
Digitized map data	Map of entire Kanto area with a scale of 1:200000 - boundary of 550 municipality zones, road network consisting of more than 6743 links, 270 OD zones. Tokyo metropolitan area with a scale of 1:50000 - 500m mesh to represent the area, more than 200 major roads extracted from kanto road network.
Environmental Data	Vehicular Emissions data Air pollution levels from monitoring stations. (Data was collected for 1979 and 1984)
Traffic data	Zone based data - Origin-Destination Tables for 270 zones. Link based data - Physical characteristics of the major roads in the network, * width of the road, number of lanes, road capacity - Traffic volume by vehicle type for major roads. (before and after truck banning) * total volume in PCU, total volume by number of passengers (Data was collected for 1984)
Landuse data	Data based on 100m mesh for the Kanto area Major classifications are (18 types): Residential, Industrial, Commercial, Institutional, Agricultural, Open space, Utilities(airports, etc.), Parks, Fish ponds. The Landuse data is aggregated based on the 500m mesh used for the Tokyo metropolitan area. (Data was collected for 1974, 1979 and 1984)
Socio-economic About 24 types data	Data based on original municipality zones. such as: Population, employment in various types of industries like - food processing, commercial services, plastic, etc. (Data was collected for 1979 and 1984)

Notes: There are different sources for the data. One of the major tasks in the application was the integration of these data which originally had different formats, etc. into a single data base.

6) By matching road network in 2) and 500m mesh GIS in 3) the affected area (500m) around each road, for residential and commercial areas was reselected.

Thus, a 500m mesh GIS with environmental, socio-economic and traffic data was established for the Tokyo Metropolitan Area. Then, expert models were developed for evaluating the impacts of the policy on about 12 indices such as - noise, air pollution, convenience for travel, business potential, etc., for residents and shop owners. The impacts

were aggregated across indices within each user group and across user groups. The evaluation showed that with the present weights while the shop owners were satisfied, residents were not so satisfied with the policy. Some color pictures are presented in Figure 8 to demonstrate the results in the application.

CONCLUSIONS

This paper has successfully demonstrated the development of an integrated approach for comprehensive evaluation of policies in urban transportation planning mainly from an environmental perspective. Without the integrated approach it is not possible to support an environmental analysis considering the multi-level aspects of urban transportation planning and the interaction among the landuse-transport-environment responsible for the urban changes. The computer-aided system, CALTEAS, developed in this research is indispensable for the practical implementation of the integrated EIA, since it combines a multi-level GIS, a simulation sub system and expert system based evaluation sub system which are essential for the assessment. The user-friendly modules and expert system in CALTEAS, to interactively select policies and evaluate from the viewpoint of different sectors of the community, enhances its distinctions. The preliminary case studies presented in this paper clearly reveal the potentiality of CALTEAS for practical applications.

Considering the enormous time and labor resources normally required for data management in the policy analyses like the integrated EIA, the rational approach in CALTEAS efficiently assimilates large volumes of data. This ensures prolific future application of the data base and the system not only in EIA or comprehensive evaluation of policies in urban transportation planning but also other general purpose planning tasks.

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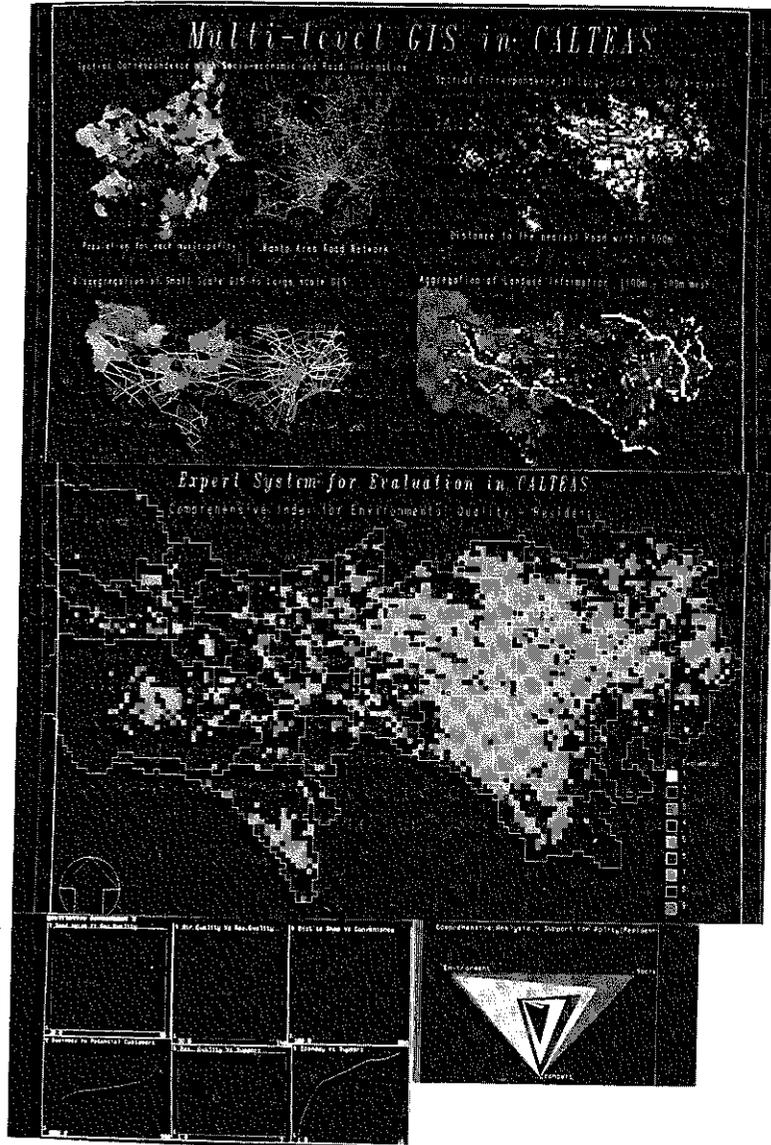


Figure 8 RESULTS OF APPLICATION OF CALTEAS