INTEGRATION OF GIS AND A GUI STYLE LAND-USE AND TRANSPORT MODEL

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Abstract: This study aims to combine a GUI (Graphic Users Interface) style LUT (Land-Use and Transport) model with GIS to make the model more users friendly and fully utilize GIS spatial analyses in LUT model. A GUI system is created with VB (Visual Basic) for the model package that consists of several sub-models. Structures, formulas and explanations of sub-models can be seen through corresponding interfaces, and simulations of sub-models can be done through GUI style. MS-Access is used to transfer data between the model and GIS internal tables to simplify the input/output of model simulations. Spatial analyses of GIS, such as buffering, overlapping and correlating data between different spatial entities are used to make the model to get input data in three dimensions. Several special functions needed by the model are developed with MapBasic and plugged into GIS database. Finally, some results of the spatial analyses are given.

Key Words: GIS, Spatial Analysis, Visualization, GUI, Land-Use and Transport Model

1. BACKGROUND

Many visions of LUT models have been developed for urban planning. Recently, in order to solve potential urban problems and realize sustainable development in mega-cities, research projects are often carried out and model packages dealing with different urban aspects are developed. Generally, a model package consists of several interacted sub-models, and cause-and-effect mechanism runs through them. For example, in "Future City Project" there are 7 working groups dealing with 7 aspects of Nagoya city (Hayashi, 1999). Models developed by the groups interacted each other; output of a group is often the input of another, vice-visa. Since all of them deal with the same city, interaction and data transfer among them have to be realized smoothly.

We think that four aspects should be considered when utilizing the comprehensive LUT model. The first is the accuracy and simplicity of exchanging input and output between spatial entities and model. The second is that model simulation should be user friendly and transparent even though its structure may be relatively complicated. The third is that sub-models should share the same data source. The forth is that model simulation should be carried out with high-speed computing language. In order to deal with the former three aspects, many LUT models use GIS database as input feeder and output container for simplifying arrangement of input data and presentation of model results. The general benefits of links between GIS and model are 1) flexible ability to spatially visualize raw and derived data; 2) provision of flexible spatial functions for editing, transfer, aggregation and selection of raw and derived data; 3) easy access to the spatial correlation between

Zhongzhen YANG

entities in the study area (Kahng, 1997). This is because that GIS database can be a digitized city, after establishing the database users can navigate the digitized city as if they walk through the real world. Furthermore, users can analyze the spatial correlations between spatial entities such as road network and traffic zone with GIS software and its language.

Here we aim to develop a GUI system with VB and GIS for a model package, which consists of sub-models developed by working groups of "Future City Project". Our system not only considers the former three aspects but also emphasizes the computing speed. In our system a GUI for implementing and explaining sub-molds is designed with VB, which can run program faster and create interfaces more beautiful that GIS language. Another GUI for spatial correlation and arrangement of data is created with MapInfo, which makes users to create scenarios, prepare input data and present model result from the digitized city directly. Because we use MS-Access as the tunnel of transfer data between model and GIS database, even though loose coupling method is used to link the two GUIs, internal data exchange is realized without knowledge of GIS source code in our system. All of the above makes our system to run model simulation faster and more users friendly. One limitation of our method is that the two GUIs cannot be seen simultaneously because they share the same set of Access tables.

2. STRUCTURE OF THE INTEGRATION SYSTEM

Actually, many efforts have been done to integrate LUT model with GIS to make the model more users friendly and transparent (Otta, 2000, Gu, 1999). Among them three main approaches can be seen, they are: 1) Embedding models entirely within the GIS; 2) Embedding the GIS entirely within models; 3) Linking of GIS and models by providing some forms of interface (Affum, 1999). The first structure involves implementing the simulation within GIS. However, up to date only a modest progress has been made. Some studies with this structure use GIS language to re-programming LUT model, but it cannot meet the demand for calculating speed. The second structure has the disadvantage of being used only for the specific task for which it was designed to accomplish. Since majority of users of GIS is in the commercial and market area, this approach will have limited usage (Affum, 1999). Two methods with this structure can be considered. The first one is use of Active-X to embedding commercial Map Engine into the model. But after embedding, lots of GIS functions got lost and edition of data becomes inconvenient. The second one is creation of all GIS functions into models by self-developed program. However, compared with commercial GIS software this is a low level GIS. The third structure can be classified from very loose coupling to strong coupling linkage. The very loose linkage involves importing and exporting various data between models and the GIS. In this case the model is run separately, model gets input from GIS external data for calculation and its output saved to files, which are then brought into GIS for display. An improved form of this is the use of DDE (Dynamic Data Exchange) to communicate between two packages. This procedure requires that both model and GIS be run simultaneously that results in increment of computer processing time. Another disadvantage is that the GIS must be supporting this DDE protocol.

The structure of our effort to combine GIS and LUT model is illustrated in Fig.1. Here loose coupling linkage is used to integrate model simulation and MapInfo database to raise the speed of model simulation, while external data exchange between them is avoided through using MS-Access. The left part of Fig.1 shows the VB-based GUI, which consists of forms and modules. Upon clicking on relevant buttons in the forms, structures, formulas or explanations of sub-models will appear for referring. Simulations of sub-models can also be run through clicking on the corresponding buttons. We will explain this GUI system in Chapter 3 in detail. The right of Fig.1 shows the GIS-based GUI, which consists of MapInfo and MapBasic. In addition to the average functions of MapInfo some customized functions for dealing with data arrangement automatically are installed. In order to avoid transfer between database and model externally, MapInfo tables are link to MS-Access tables. This is very easy since MapInfo offers an option for users to save its tables in MS-Access style. A ordinary MapInfo data set consists of 4 files with expanded names of *.tab, *.id, *.data and *.map respectively, while there are 5 files in MS-Access style MapInfo data set since a "Access table" is added to it. This linkage makes the data in MapInfo and MS-Access tables correspond to each other, any changes in one table will cause the relative changes in other table. Moreover, this change happened automatically upon saving the edited tables. This makes the data flow between model and digitized city more easily, rapidly and accurately. The middle of Fig.1 is a MS-Access platform, it includes both MapInfo linked tables and ordinary data tables, while both of them can be treaded for making queries, writing reports and creating forms.
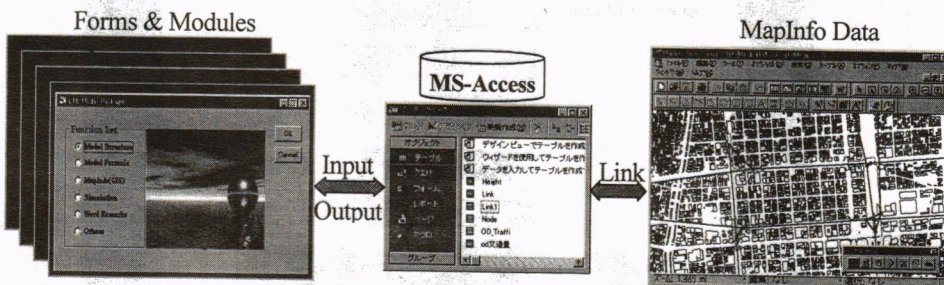

Fig.1 Structure of the GUI System

3. VB-BASED GUI FOR LUT MODEL

Since a model package includes several sub-models, its structure and framework are relatively complicated. As a result it is hard for a researcher or planner to run it in traditional environment because he has to find all of the programs and I/O (input/output) formations. Then it is necessary for us to establish a GUI system to make users carry out model simulation and access model structure, formula, explanation and result with dialogue style. In VB-based GUI system forms and their contents (such as command buttons) are used to design dialogues between users and computer and modules are used to code the model simulation.

The main interface is illustrated in Fig.2. There are six radio buttons for users to access model structures, model formulas, model explanations, model simulations, GIS tables and other information respectively. We can view or run a sub-model by selecting a corresponding button and

clicking "OK" button in the interface. For example, when "**Model Structure**" is selected and "**OK**" is clicked model structure dialog will appear as Fig.3 shown to let users know how many sub-models exist, and further upon double clicking on a button in Fig.3 description of the structure of the corresponding sub-model appears as Fig.4 shown. We can also look into sub-model formulas and carry out simulation by clicking on "**Model Formula**" and "**Simulation**" respectively. We also install MapInfo into VB form through Active-X while the aim of this is not to edit data but display data or simulation process, such as the simulation of transfer behavior of travelers in a station.
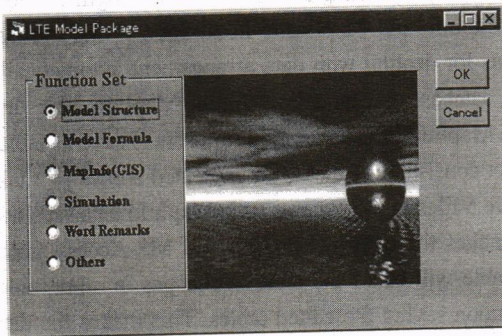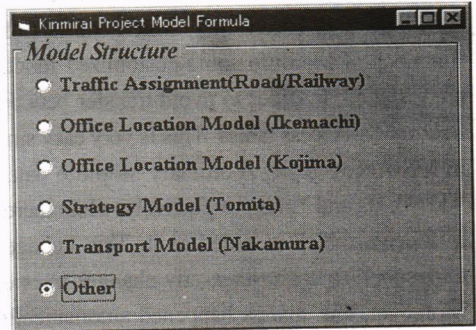

Fig. 2 Control Panel of Model Package   **Fig. 3 Model Formula Dialog**
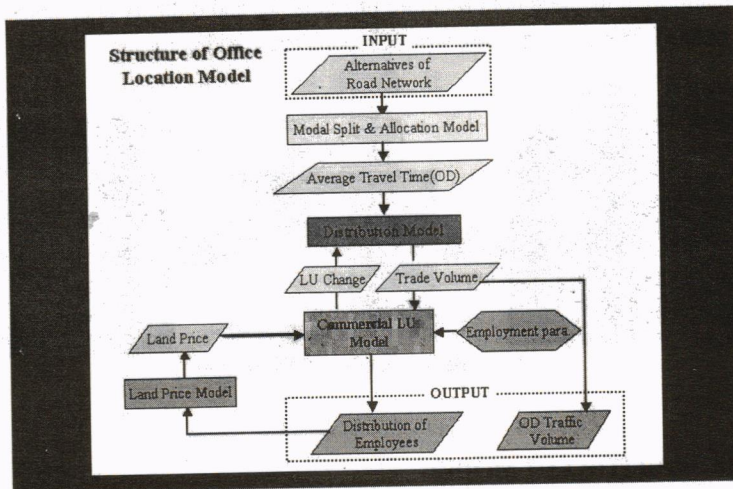

Fig. 4 An Example of Display of Model Structure

In addition to MapInfo, MS-Office is also needed in the system, since MS-Word is used for model comments, MS-Excel is used for save model parameters and MS-Access is used as data input/output tunnel. Since we install all of the sub-models into the above GUI system and input/ output is linked with GIS database automatically, users outside the project can also use sub-models developed by the working groups without any difficulty. Based on a standardized format of GIS tables, users can process or arrange data of the studied city on GIS without considering the formation and saving place of the input files. What users need to do is to handle data on the digitized city with GIS and saving the change data. Since GIS tables are automatically linked with MS-Access tables, after saving the changed GIS tables users can run sub-models to analyze or simulate the urban phenomena based on the digitized city through MS-Access tables. Moreover after finishing the

simulation, analyzed or simulated results can be displayed on the digitized city with the same GIS data set.

Since all raw data are prepared in MapInfo database, we can say that a digitized city is the data source of the sub-models. Even though GIS has a relatively strong GUI function, some special functions such as auto spatial correlation need to be created into MapInfo in order to transfer input/output between the model and digitized city effectively and link model with database dynamically. In next chapter we will explain the structure and mechanism of the GIS-GUI system as well as the merits of inverting all raw data into MapInfo tables and creation of the digitized city.

4. DIGITIZED CITY AND FUNCTIONS OF GIS-BASED GUI

Models without data cannot become tools for urban planning and policies analyses. In LUT models there are two sorts of data, namely spatial and attribute data. Spatial data show the geographical position of urban elements, such as the traces of roadways, outline of TAZ (Traffic Analysis Zones) and locations of intersections or railway stations. When applying LUT model we have to identify the correlations between these geographic elements. For example, it is necessary to know the start and end intersections of a roadway when calculating the shortest route between nodes in road network. Attribute data show some characters of the spatial entities, such as population in a TAZ, lane number or design velocity of a roadway. Because LUT models analyze interactions between spatial and attribute data, we should manage them as a whole. We can say that the best tool for managing them is GIS since it integrates spatial and attribute data to make the urban database into a digitized city where users can navigate as if they walk through the real city. Users can read attributes as they point mouse on a spatial entities in GIS window. In our study, the digitized city consists of:

1) TAZ. Such as administration zone, school zone, PT survey zone;
2) Transport network. Such as road network and railway network;
3) Grid population. In order to calculate population for different TAZs $500m \times 500m$ grid is used as basic population holder;
4) Land-use data. Urban land is divided into parcels according to their usages;
5) Building data. All buildings in the city are indicated with structure, usage and story.

Since urban planning begins to utilize digital data rather than paper maps, lots of the above-mentioned data could be obtained in digital style. In fact we just digitized a few data from map when we establish our digitized city. However, integration of different layers and correlation of different spatial entities with an effective method are very important. We use Mapbasic to deal with these items and create all of the spatial analyses into GIS window with GUI style. These GUI style functions are explained as follows.

4.1 Transport Network Correlation

Transport network in LUT model consists of links and nodes, as one of the inputs the nodes and

Zhongzhen YANG

links have to be arranged in a decided format. This format should be able to distinguish the start and end nodes of each link. Without GIS the arrangement is very complicated and time/labor cost since same works have to be done manually for different transport planning scenarios. Different from traditional network, both links and nodes in our networks have physical meanings since we make the network as a part of the digitized city. Based on it we realize an automatic data arrangement of transport network with GIS's spatial analysis, its process can be described as:

1) Digitizing road or railway sections to obtain a link layer (Fig.5). Links in this layer are created based on the raster map and can represent the central lines of roadways or railways. Here links are in Polyline styles, thus we can calculate the geographic lengths of roadways or railways with "**ObjectLen()**" of MapBasic (MapBasic Users' Guidebook, 1995) in MapInfo easily.

2) Finding intersections of the links and creating points in the intersections to obtain a node layer.

3) Matching nodes and links to form the network. In both link and node layers, IDs of them can be calculated automatically, then as shown in Fig.6, with "**Obj Contains Obj**" we can find nodes 618 and 624 are two ends of link 470. If link 470 is a two-directions one it needs not to distinguish the start and end nodes, otherwise we have to distinguish them. XY coordinates of nodes 618, 624 and start and end points of link 470 can be calculated by "**GeoraphyInfo()**". Then through pair comparison we can judge that 618 is the start node and 624 is the end one.

Steps 2 and 3 can be programed with MapBasic and the program can be assigned to a command buttton in GIS window. Then corresponding to network scenarios the correlation between nodes and links can be found by clicking on the button.
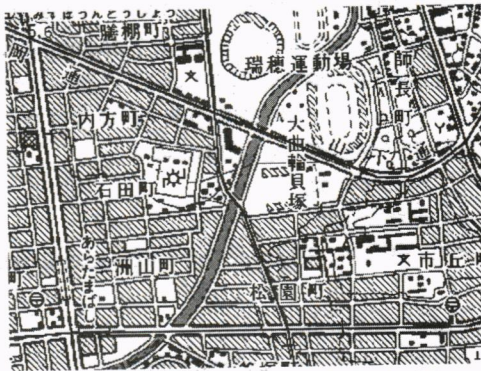

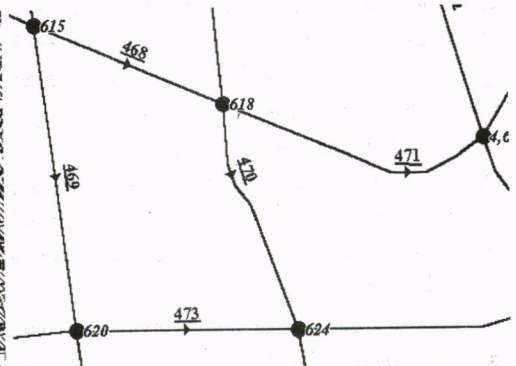Fig. 5 Links based on Roadway in Raster Map   Fig. 6 Correlation between Links and Nodes

Different from in road network, in railway network we have to take transfer between lines into account. Therefore, in addition to the three steps, dummy links between transferable stations should be create to let model know where transfer might happen. There are two kinds of transferable station as described below. First, riders can change one line to another in the intersections where more than one railway lines intersect each other. There should be a link in the model to represent the transfer path, therefore, here one node should be divided into several nodes and dummy link between the nodes should be added (Fig.7). Second, even though several lines do not intersect each other but there are some stations within walking distance (circle in Fig.8) of a station, then transfers between these stations are also possible and dummy links should be added (dot lines in Fig.8). After finishing the spatial correlation, we input the needed attributes data such as lane number and Q-V curve of link, running time of railway link and timetable of a station to obtain a completed transport network.
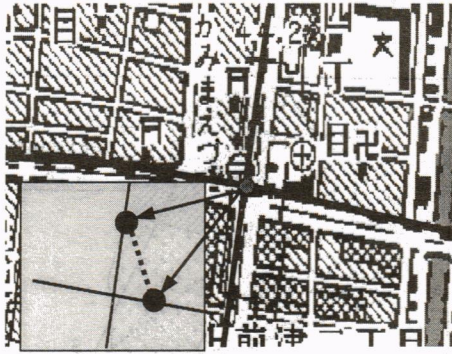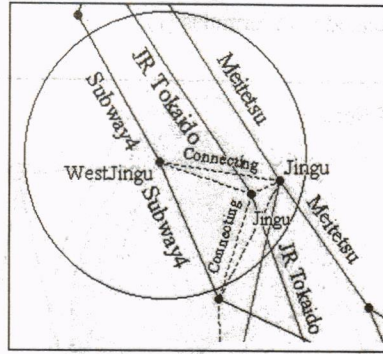
Fig. 7 Dummy Link between separated Stations

Fig. 8 Dummy Links between different Stations

4.2 Connecting TAZ with Network

In urban planning traffic is considered originating from TAZs, entering transport network and finally destining also at TAZs. Among LUT model, land use model analyzes urban behavior based on TAZ and transport model analyzes traffic flow based on transport network, while OD traffic is their interaction. Here OD traffic data are connected with transport network through access and egress nodes. Traditionally OD traffic are considered originating from and destining at centroids of TAZs and the nodes nearest to the centroids are considered as the access and egress ones. In transport model links are supposed to exist between centroids and its nearest nodes. This kind of connection between TAZ and transport network is static one. Since it is rational to think that not all of the traffic in a zone origins from or destines at zones' centroids and OD traffic may enter transport network through several node rather than the nearest one, OD travel time estimated with this method is not accurate enough to guarantee the accuracy of the model. In GIS-based digitized city, dynamic connection between TAZ and transport network can be established to raise the accuracy without adding working time/cost seriously. Here dynamic connection means that nodes within a certain area around a TAZ might be the access or egress ones. Therefore, there may be several access or egress nodes for a TAZ. Based on GIS spatial analyses, we can pick up all of the access or egress nodes for a zone and calculate the probabilities of OD traffic to select each pair of nodes. The method of dynamic connection and probabilities calculation is described below.

We think that access and egress nodes should be within a certain area around a TAZ. Though the area changes according to the abbreviated degree of the network, while here area 500m larger than the TAZ is supposed to be a reasonable one. Then all nodes within this area can be found in GIS database (Nodes 1-5 in Fig.9) and probabilities of OD traffic to select each node can be calculated. Here commuting OD traffic is used to explain the method of calculation of the probabilities with spatial analyses. The principle of the method is to divide a TAZ into several sectors and estimate the ability of generation and attraction of OD traffic in each sector. As Fig.10 shows that the boundary line of two sectors is in the middle of two dot lines, which are made up of centroid of the TAZ and the two neighboring access or egress nodes. Then we use sectors' night population of 20-64 years old and office/factory spaces to estimate the generating and concentrating capacities of commuting traffic in each sector respectively, and the probabilities of OD traffic selecting a pair of nodes can be

Zhongzhen YANG

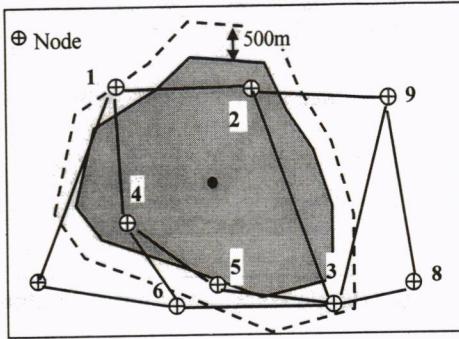calculated with formulas (1).
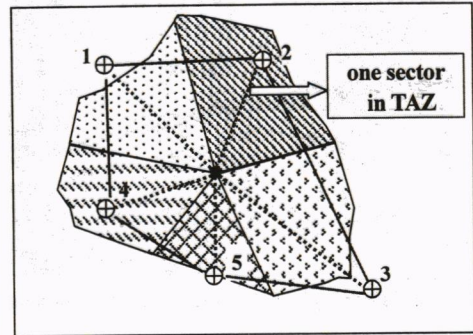

Fig. 9 Potential Access or Egress Nodes

Fig. 10 Division of Traffic Zone

$$P_{ij-rs} = \frac{\theta_i \vartheta_j / t_{ij-rs}}{\sum_i \sum_j \theta_i \vartheta_j / t_{ij-rs}}$$ (1)

t_{ij-rs} : the shortest traffic time between traffic zones r, s by taking nodes i, j as access and egress nodes respectively.

θ_i : ratio of population in sector i to zone's total population.

ϑ_j : ratio of office & factory spaces in sector j to zone's total office & factory space.

In order to know the ratios, we have to estimate the population and space in each sector based on building and $500m \times 500m$ grid layers. In the case of population, we found that resident buildings in building layer are divided into two kinds, namely detached house and apartment, then a statistic equation can be formed as formula (2).

$$Pop_i = \alpha S_{Di} + \beta S_{Ai} + \lambda$$ (2)

Pop_i : Population between 20-64 years old in a grid.

S_{Di}, S_{Ai} : Floor spaces of detached house and apartment respectively.

α, β, λ : Being estimated parameters.

Tow kinds of floor spaces in each grid can be calculated through overlapping building layer onto grid layer. After estimation of the parameters, we can calculate population for each building grid by grid with formulas (3.1), (3.2). Therefore, needed population in each sector can be obtained through summing up the population in the houses located in the corresponding sector. While office/factory space can be calculated directly by overlapping building layer to TAZ layer.

$$Pop_{ij} = \alpha S_{Dij} + \beta S_{Aij} + \lambda$$ (3.1)

$$\sum_j^n Pop_{ij} = Pop_i$$ (3.2)

Pop_{ij} : Population between 20-64 years old in building j of grid i.

S_{Dij}, S_{Aij} : Floor spaces of detached house or apartment in building j of grid i respectively.

n : Number of residential buildings within grid j.

We also assign the algorithm based on the mentioned process into a GIS command button to make

the calculation be carried out through GUI style.

4.3 Three Dimensions Road Network for Analyzing Pollutant Emission

The objective of most research projects is to find a way for sustainable and environment friendly urban development. To decrease pollutant emission of automobile through land-use planning and transport demand management are the ideas. In both of them pollutant emission from automobiles should be estimated according to traffic flow on road network. It is common to use "running speed model" to analyze this pollutant emission. In the model even though traffic volumes and average velocities on road links are the main factors, roadway grades are also directly related to elevated emissions because they have significant impacts on engine loads. Unfortunately, grades have been largely ignored in current regulatory models (Bachman, 2000). This is because that without GIS it is impossible to calculate grades of roadways in urban road network. Here we just explain our method to create a 3-D road network with GIS spatial analysis, and the methods of integrate the grades into traffic assignment and emission models will be beyond this paper.

In order to estimate grades of roadway height data is necessary, here $50m \times 50m$ grid DEM (Digitized Elevated Model) data is used. The following steps are needed for transferring DEM data to roadway and calculating their grades.

1) Creation of a height point layer. After selecting a polyline that represents a physical road section, we calculate all of the vertices on it to get a group of points represent by XY coordinates. First, we created points with these XY to get a part of the height point layer. Second, supposing an interval of 200m long can reflect the vertical change of roadway, additional points between neighboring vertices with interval of 200m are inserted into the height point layer if the distances between the neighboring vertices are more that 200m long. (Fig.11).

2) Calculation of height of each point. Overlapping DEM layer onto height point layer, grid in which a height point is located can be found, and height of the grid can be considered as the height of the point (Fig.11)

Then a table like Table 1 can be obtained and grades of sections in each link can be calculated with formula (4). This process becomes another command button and all of the customized buttons are installed onto a customized button pad.

$$g_{l-ij} = \frac{(H_j - H_i)}{\sqrt{(X_j - X_i)^2 + (Y_j - Y_i)^2}} \tag{4}$$

Table 1 Height Point along Roadway

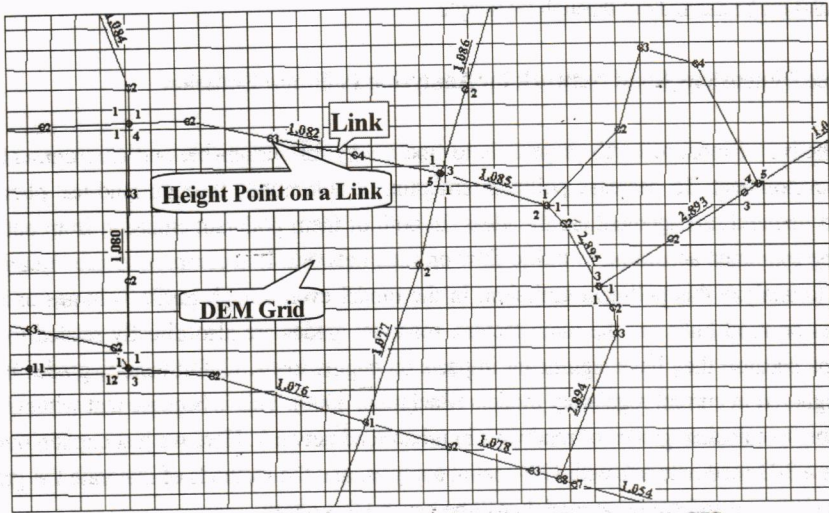| Link ID	Origin	Destination	Point 1	Point 2	...	Point n
L_1	O_1	D_1	X_{11}, Y_{11}, H_{11}	X_{12}, Y_{12}, H_{12}	...	X_{1n}, Y_{1n}, H_{1n}
L_2	O_2	D_2	X_{21}, Y_{21}, H_{21}	X_{22}, Y_{22}, H_{22}	...	X_{2n}, Y_{2n}, H_{2n}
...	...	...	...	...	...	...

Zhongzhen YANG

Fig. 11 Mechanism to calculate Grades of Roadway in GIS

5. APPLICATION OF THE MODEL

Even though all of the spatial analyses are carried out, here we just show a part of the results. In order to assign OD traffic to road network, which is the most important calculation in model packages, first we estimated formula (2) with the population and buildings data in Nagoya city. There are totally 1068 of $500m \times 500m$ grids with population covering Nagoya city and about 0.4 million of buildings in the same area. The estimated parameters are shown in Table2 and the estimated and actual data are compared in Fig.12. We can say that the estimation has a good fitness.

Table 2 Estimated Results of Formula (4)

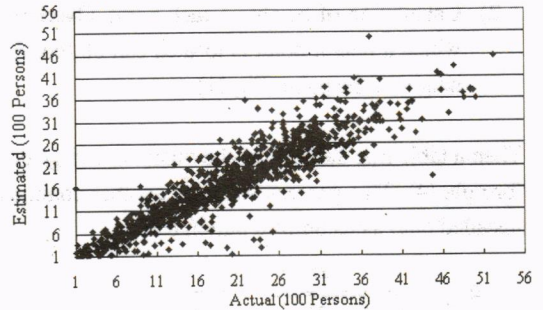|	Value	T-Value	R-Value
α	0.0182	40.2	
β	0.0225	56.8	0.91
λ	263	9.3	

Fig.12 Comparison of Estimated and actual Population

Second, we should calculate θ_i, ϑ_j for each origin and destination zone. This is not an easy work since before overlapping building and TAZ layers we have to search access or aggress nodes for each TAZ and divide it into several sectors as shown in Fig.10. The algorithm for calculating θ_i, ϑ_j is based on MapBasic and described in table 3. further, an example in GIS is shown in Fig.13.

Table 3 Algorithm of Calculating Population Ratio of each Sector to TAZ

| Steps	Variables
Step1: Calculating the centroid of TAZ and the rectangle that contains the TAZ	$X, Y, X_{min}, Y_{min}, X_{max}, Y_{max}$ $R = \sqrt{(X_{min} - X_{max})^2 + (Y_{min} - Y_{max})^2} / 2$
Styep2: Creating a 500m buffer for the TAZ and finding nodes within the buffer	$X_i, Y_i, i = 1,..., n$ (one ends of the dot lines)
Step3: Calculating directions of the dot lines in Fig.10 and renumbering the nodes according to the directions.	$\alpha_i, i = 1,..., k, k+1,..., n$ $\alpha_k < \alpha_{k+1}$
Step4: Creating the Lines in the middle of the two dot lines.	$Line_j = CreateLine\{(X_j, Y_j)(X, Y)\}$ $X_j = X + R \times Cos[(\alpha_{i+1} + \alpha_i)/2]$ $Y_j = Y + R \times Sinc[(\alpha_{i+1} + \alpha_i)/2]$ $j = 1,..., n; \quad i+1 = 1, when: i = n$
Step5: Adding lines $((X,Y),(X_{min},Y_{min}))$, $((X,Y),(X_{min},Y_{max}))$, $((X,Y),(X_{max},Y_{max}))$ and $((X,Y),(X_{max},Y_{max}))$ to the lines group and numbering them according to the directions.	$\alpha_i, i = 1,..., k, k+1,..., n+4 \quad \alpha_k < \alpha_{k+1}$
Step6: If the ends of neighboring lines do not include vertices of the rectangle then creating triangle, otherwise creating region.	$Triangle_i = Create\,Region(3, (X,Y), -$ $(X_i, Y_i), (X_{i+1}, Y_{i+1}))$ $Region_i = CreateRegion(m+3, (X,Y), -$ $(X_i, Y_i),..., (X_{i+m}, Y_{i+m}))$
Step7: Overlapping objects created in Step6 to TAZ	$Sector_i = Overlap(Triangle_i, TAZ)$
Step8: Overlapping sectors to building layer	$Houing_{ij} = Overlap(Sector_i, Bulding)$
Step9: Summing up population or spaces in housings and calculating the ratios	$P_i = \sum_j Pop_{ij}, \theta_i = P_i / P_{TAZ}$
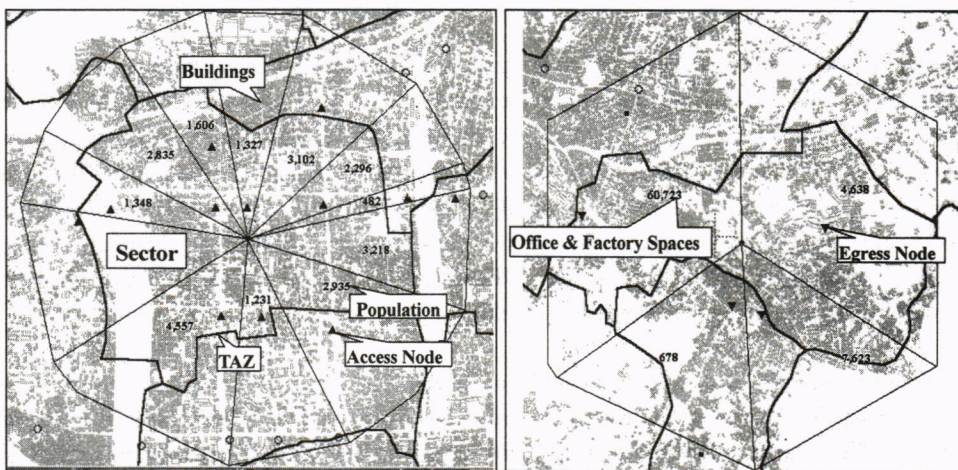
Fig.14 Example of Division of a TAZ and Estimation of its Traffic Generating or Attracting Abilities

The right in Fig.14 is an origin zone and totally 12 access nodes exists. The left in Fig.14 is the corresponding destination zone and totally 4 egress nodes are found. Division situation and calculated people and spaces data are also illustrated. Table 4 shows the probabilities of the OD traffic selecting some pairs of access-egress nodes.

Table 4 Some Examples of the Calculated Probabilities

Node Pair	Probability	Node Pair	Probability	Node Pair	Probability	Node Pair	Probability
223- 493	0.08552	223- 501	0.00452	223- 502	0.00075	223- 523	0.00824

An example of calculation of link grade is given in Fig.14. Here horizontal axis shows the distance from the start node to the height point in the roadway and vertical axis shows the heights of the points. Totally, 35 height points are pick out in the roadway (Link 1239) and grades between two points are calculated.
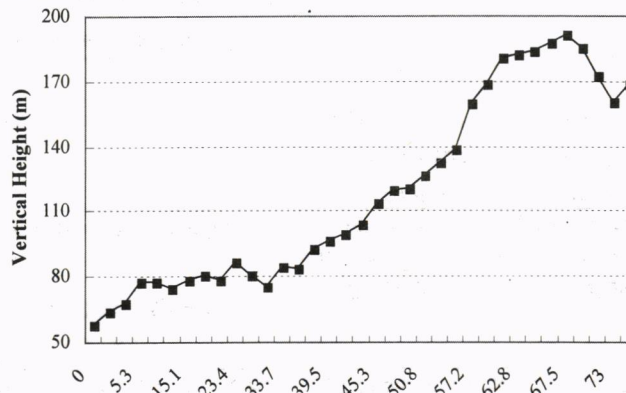

Fig.14 Example of Calculation of Grades on Roadway

6. CONCLUSIONS

This paper reported a system developed to integrate a LUT model with GIS to make the model more users friendly and utilize spatial analyses more effectively in the model. Using GIS, MS-VB and MS-Access, we visualized a LUT model package to make its sub-models be run and shown transparently. This kind of visualization is users friendly, and users can reach and test all sub-models through icons and buttons. After integration of the model with GIS, all inputs and outputs of the model could be got from and sent to GIS layers via MS-Access tables. Therefore, users can view the results of model simulations and analyses in digitized city with our system as if they check the effects of urban planning policies in the real world.

With our system, existing data could be used more intensively since spatial analyses were applied to deal with data in different spatial entities. In order to carry out spatial analyses, special algorithms were complied. Modules for arranging input and displaying output of the model were created and installed into GIS to realize a GUI style data correlation. Moreover, vertical attributes of roadway in road network were considered when estimating pollutant emission from automobile traffic.

ACKNOWLEDGEMENTS

REFERENCE

Bachman William *et al.* (2000). Modeling regional mobile source emission in a geographic information system framework, **Trans. Res. C 8**, 205-229.

Otto Anker Nielsen *et al.* (2000). A Large-Scale Model System for the Copenhagen-Ringsted Railway Project, **IATBR2000 (CD-ROM)**, Application Workshop 4, Queensland, July 2000.

Affum Joseph K *et al.* (1999). Integration of Geographic Information Systems and Models for Transport Planning and Analysis, **Selected Proceeding of the 8th WCTR**, Vol.3 pp295-308.

Hayashi Y. (1999). *1998 Report on Future 3D City Planning Research Project*. Nagoya Industrial Science Research Institute 1999.

Kevin Q. Gu *et al.* (1999). Data Presentation and Visualization for Land Use and Transport Models, **Cupum '99 (CD-ROM)**, G15, Venice, September 1999.

Kahng Byong-Kee *et al.* (1997). The Analysis of Urban Spatial Changes of Seoul with GIS, **Proceeding of International Symposium on City Planning**, Nagoya, 1997, pp291-299.

MapBasic Users' Guidebook (1995). MapInfo Corporation, Troy, New York