A PERSON TRIP SIMULATION SYSTEM FOR EVALUATING TRAFFIC MANAGEMENT IN A CENTRAL BUISNESS DISTRICT

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Abstract: The traffic condition in a central business/commercial district (CBD) dominates whole-city usage of traffic modes as well as attractiveness of CBD. Thus traffic management in CBD is a critical issue from the viewpoint of the whole-city transportation system as well as of local traffic service. The simulation system being developed in this study aims to evaluate the effects of traffic management policies with several distinctive features, including: (1) reproducing traffic conditions in detail level of block, with flexible and seamless network description by using GIS as the platform, (2) treating "walk" as an important mode, (3) modeling traffic system performance considering interactions between modes and/or links.

1. INTRODUCTION

The central business/commercial district (CBD) attracts large amounts of person trips for commuting, business, shopping, *etc*. And it is well known that modal choice of line-haul is affected largely by the level-of-service (LOS) of feeder, *i.e*. access/egress. The traffic condition in CBD, therefore, dominates whole-city usage of traffic modes as well as attractiveness of CBD, which could be a representative of vital power. In these senses, traffic management in CBD is a critical issue from the viewpoint of the whole-city transportation system as well as of local traffic service. In addition, although large efforts have been made to deal with a great increase of traffic demand recently, problems like traffic congestion, traffic accident, and environmental pollution are still grave concerns.

In order to relieve these problems, traffic management policies for harmonizing reducing car-usage with improving mobility of citizens, such as Transit Mall, Fringe Parking, introducing short-range public transport, *etc*. might be applied. However, there are few traffic simulation systems adequate to evaluate such traffic management policies that promote multi-modal trips. In case of such analyses are intended to carry out, detail and large-scale data such as origin and destination zonation system, transportation network for each traffic mode, travel demand, *etc.* are indispensable. These data cause high cost of collecting and constructing the database, also can be complexity of its management and handling, and voluminous. Concerning these obstacle, the rise of Geographic Information System (GIS) facilitates efficient data storage and handling. GIS extends a capability of developing the system which analyze such traffic management policies as mentioned above. GIS also assists evaluation and decision process of policy through geographical presentation of the analysis result.

The simulation system being developed in this study aims to evaluate the effects of such traffic management policies on traffic conditions, based on GIS platform. The distinctive features of the simulation system are as follows:

1) produces traffic conditions at the detail level of block as for CBD, and has flexible and seamless network description to be able to arbitrarily focus or browse the area concerned,
2) considers mode choice behavior as well as route choice with treating "walk" as an important mode and focusing relationship between line-haul choice and access/egress choice,
3) models traffic system performance (LOS) considering mutual interaction between modes and/or links, especially in the mixture of pedestrian and car on a non-separated street, and pedestrian crossing versus car flowing.

This paper firstly describes the framework and main structure of the system. The system consists of three major sub-systems: a) network database and representation, b) travelers' choice behavior, and c) mode/link performance. They are integrated on the GIS as a platform. Details of the original concepts of each sub-model and mutual interaction between them are described. Illustrative examples of the prototype system implemented are also shown.

2. CURRENT ISSUES AND A CONCEPT OF THE STUDY

There are a great many of researches on theory and system development of automobile network flow simulation (*e.g.* Sakamoto *et al.*, 1998). Above all, studies about system design adopting the GIS as a platform is exceedingly active field recently, because of its enhancement of capability to store, manage and handle spatial data. Also, mainly in automobile and/or bus mode, there are some attempt to design database regarding multi-modal network representation (Miller and Storm, 1996).

On the other hand, researches about behavior of walker, corresponding to pedestrian mode, are also well investigated (*e.g.* Lovas, 1994). So it is able to model pedestrian traffic flow sufficiently.

However, there has practically been no precedent that developed a traffic simulation system adopting a walking as one of the major mode and entirely considering interaction between each modes. At most, there are several examples like a micro simulation system, which is only focused on several intersections, if any.

This study is to develop a system, which is able to simulate multi-mode traffic flow, including a mode of pedestrian. The approach of this study is to improve the macro simulation on network in respect of its network representation. Concepts of generic database design as well as methods of representing traffic network in detail in block level are described. By application of the model to network and data assuming actual condition, we examine the capability of this system. In addition, some example snapshots of graphical results by the current prototype system are shown to illustrate the feature of the system.

3. SYSTEM DESIGN

This section describes the database system design, and the method of constructing the multi-mode network for traffic simulation.

3.1. Generic Data Structure

The database design proposed is to maintain a single database of a physical network. This network data only helds the physical connectivity of transportation network. However, accompanied with this base data, additional attributes of links and nodes required for generating the multi-mode network are also holded. Figure1 illustrates the basic data structures. Note that Figure1 illustrates only the fundamental data, so other ancillary data can also be included in the database.

A key feature of this database structure is that a *Base Node* has attributes "Whether has Parking" and "Whether is PT Stop" ("PT Stop" means public transportation mode's stop, *e.g.* bus stop or railway/subway station). These attributes implicitly indicate that any node can be a centroid, *i.e.* origin/destination of person trip. In case that a link is not parted corresponded with public transit stops, dividing the link referring the position of stop along the link can generate the state of data structure equal to Fig.1.

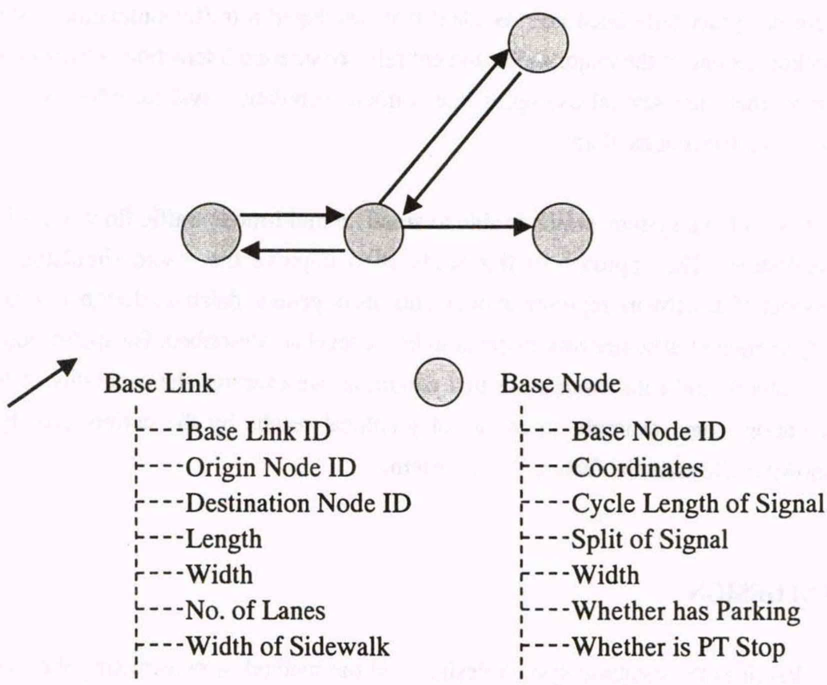

Figure 1. Basic Data structure and Example of Physical Connectivity

3.2. Method of Expressing Multi-mode Network

Figure2 represents the overview of the process of generating multi-modal network based on the base network data structure described in the previous section. At first, sub-networks corresponding to individual modes are generated from the base network as separated network layers. Then, multi-modal, *i.e.* the *Virtual Network* including *Mode Transfer Links* among network layers is synthesized. Following sections explain the each step of process in detail.

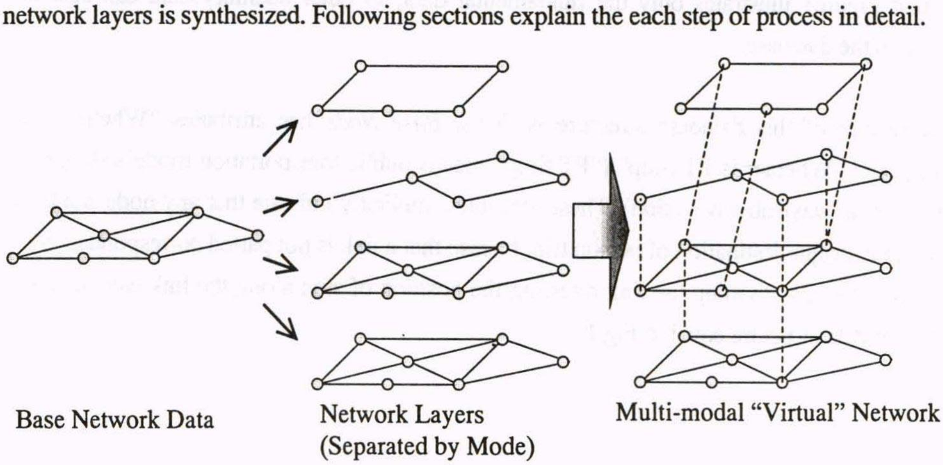

Figure 2. Overview of Process of Generating Multi-modal Network

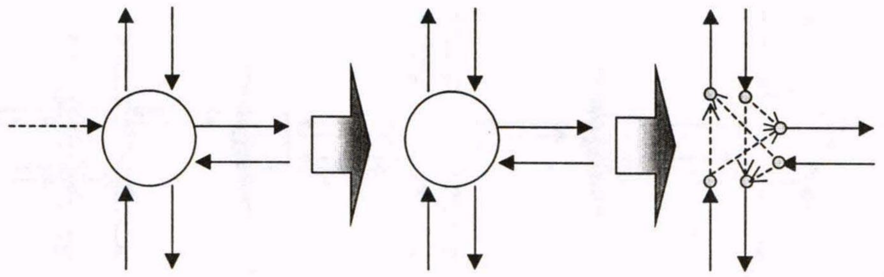

Figure 3. Process of Generating Automobile Network Layer

3.2.1. *Automobile Network Layer*

Figure3 illustrates this process of generating automobile network at an intersection. Referring whether a base network link has lane(s) for automobiles, in other words, whether cars are able to run along the link, automobile network layer is simply generated. At the separation procedure, automobile network link inherits almost all of attributes from base network link. At the same time, each link defines its initial capacity with its own attributes, such as number of lanes, width and so on.

Then, the intersection node is modeled as a sub-network in order to represent the directional delay. Intersection links are created between the separated nodes. Both separated nodes and intersection links inherit the intersection node's ID. This inheritance makes it possible to consider the corresponding interaction between automobile and pedestrian network at each intersection.

3.2.2. *Pedestrian Network Layer*

Differing from automobiles, pedestrians can walk along the link independently of base link's direction. In the pedestrian network layer, consequently, parallel pedestrian links are generated referring base network link. A Pedestrian link inherits attributes from base network links, except its width which comes from base link's width of sidewalk.

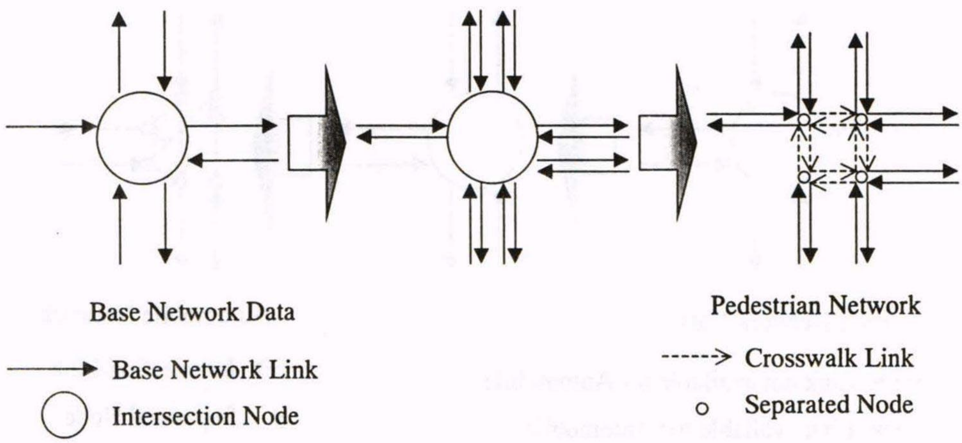

Figure 4. Process of Generating Pedestrian Network Layer

And then, similar to automobile network layer, intersection node is modeled as sub-network containing separated nodes and crosswalk links. Also these nodes and crosswalk links inherit the base intersection node's ID. Figure4 illustrates the process of generating a pedestrian network.

3.2.3. *Transit mode Network Layers*

Referring information defined within the base network data about which base link belongs to transit route(s), a transit mode network is represented as a set of separated route layers. This process is quite simple, but takes an important role regarding database entirety. This concept is described in the next section. Figure5 is a simple example of transit mode network generating process in case that two bus routes exist.

3.2.4. *Multi-modal Virtual Network*

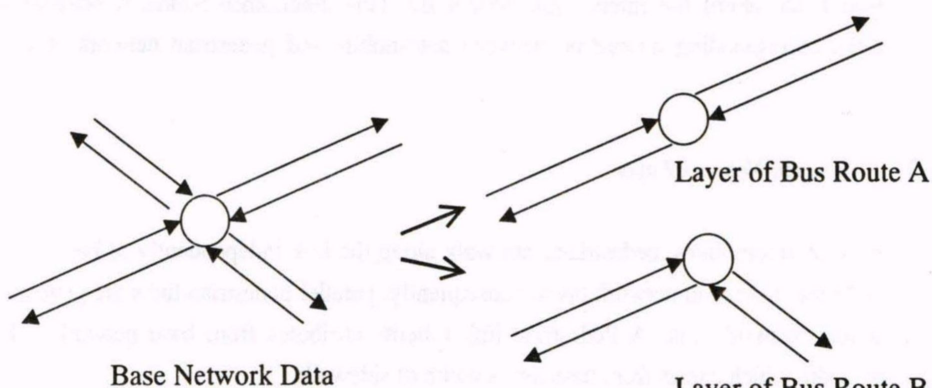

Figure 5. An example of Generating Route-based Transit Mode Network Layers

After all the process of generating individual modal networks, layers are mutually referenced so as to define whether it is possible to transfer between each layers. For example, between certain subway network layer and pedestrian network layer, referring the base node's "ID" and "Whether is PT Stop" dummy links representing transfer are stretched. These dummy links must have proper link costs corresponding to transfer costs such as fare and waiting time.

In most of the conventional methods, a base data-base holds separated sub-networks for each mode and dummy links among these sub-networks in order to represent entire multi-mode network. This can cause database entirety problem on database modification since there are some dependencies among sub-networks. For example, a bus network strongly depends on an automobile network, so deleting an automobile network link without corresponding bus network's deletion results database inconsistency. In our database design, base network data only holds physical attributes, and referring it subsequently generates modal network layers. This means that base data modifications are reflected in each network layers.

3.3. Link Performance and Interaction Among Modes

Each link performance is modeled as a function of the link traffic volume and the capacity. This performance is defined with interaction among layers such as waiting time at intersection and so on.

Note that the data structure described above is put to good use for considering the intersection among modes. It is possible for a certain layer to know whether a link crosses versus another layer's link, goes along the same lane, *etc.* by referring the inherited ID from base network data. That is to say, a certain layer can consider impact from the other layers' traffic condition.

3.4. Choice Model

The choice Model System is one of the elemental sub-system of simulation system. Also this sub-system consists of three sub-sub-systems; OD trip model, modal choice model, and route choice model. On execution of the simulation system, OD trip volume data is exogenously given. Modal split rate is determined by using logit model, and route choice is determined with definite minimum path choice. These models are implemented in the whole simulation system as independent modules. Therefore, analysts can easily change these models as the occasion may demand.

4. APPLICATION

In this study, we practically applied the system to network and OD trip data assuming the CBD of Sendai City. Although the data is supposititious because of the incompletion of GIS engine, it has been prepared conforming to reality exceedingly. Figure 6 shows the structure of the test network. It consists of 191 links and 74 nodes. Each bold line link and dotted bold line link represent two bus routes (refer to the following section). Using the system of spatio-temporal data conversion (Uchida *et al.*, 1999), OD trip data is converted into detailed block level from zone-level data of Person Trip Survey conducted in Sendai Area.

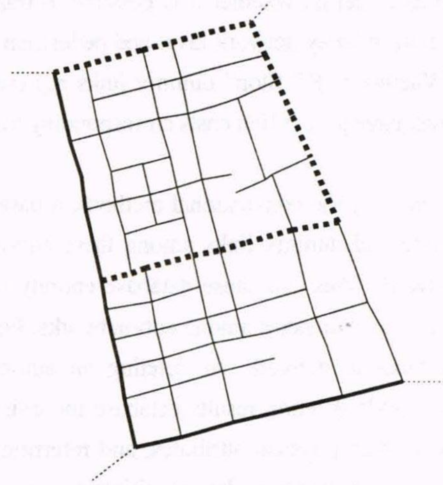

Figure 6. A Test Network.

The prototype system is now still in its developing stage. Some features described above have not yet been implemented.

4.1. Procedure of Calculation

Figure7 shows the outline of the simulation process of the current system as a flow chart. At first, a multi-modal virtual network is generated. In current implement, two network layers are considered, one is an automobile network layer and the other is the virtual network layer consists of bus network layer(s) and pedestrian network, and given OD trip is split into these layers. Then, traffic volume is loaded with all links in minimum path between OD pair. At the time, one layer's link cost is interacted with the other layer's traffic condition. Broken line arrows represent this interaction. Finally, if the finishing condition is satisfied the iteration is terminated, otherwise, modal split is re-calculated, and these procedures are iterated. This finishing condition is currently only the limit of the number of iteration, so it is needed to establish a convergence requirement condition in future version.

4.2. Calculation Results and Graphical Presentation of Current Prototype System

In this section we describe the result of a practical application of the system with illustrative

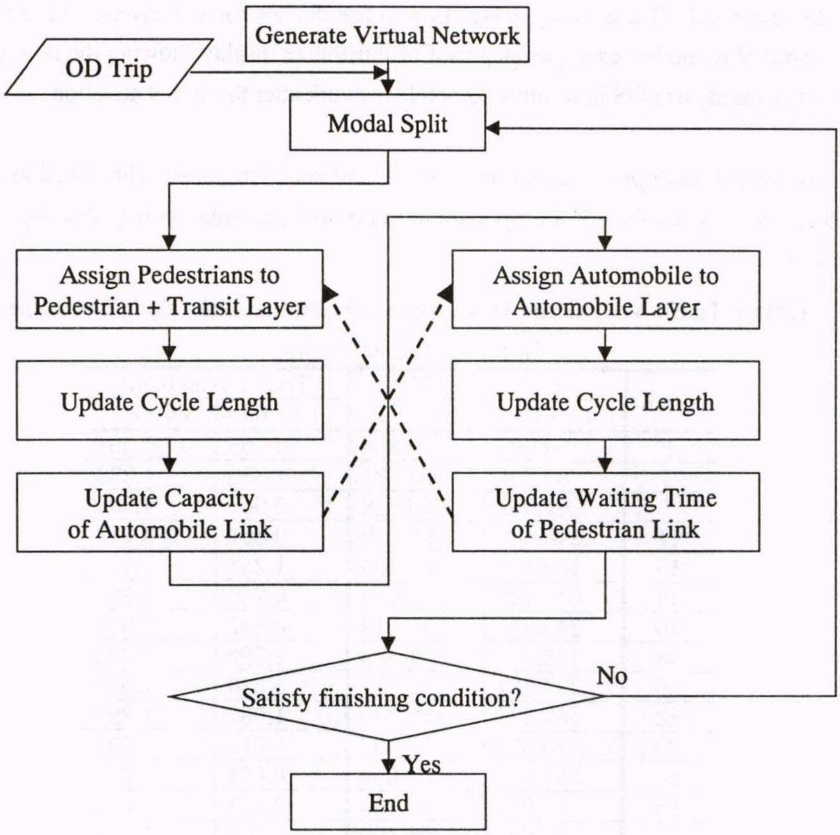

Figure 7. Flow Chart of Simulation Procedures

outputs. It is assumed that there was one bus route "1" in the network showed as bold line links in Figure6, and would be adopted a policy to add another bus route "2" showed as dotted bold line links. So as to consider whether system could properly represent effect of the policy, we focus on links along the added bus route 2.

Table1 shows the traffic volume and travel time of each pedestrian link along by the bus route 2 before and after the policy is adopted. Hatched sequential set of links in this table signify a section between bus stops consist of these links. Total traffic volume, especially on route from link ID 1 to 60, is reduced after the policy adoption as against the increase of travel time. This result implicates that the policy brings mode change from walking to bus route 2 for pedestrians. And also, this can be interpreted that the system is representing effect of traffic management policy as well as interaction between each layers and mode reasonably.

Figure8 is an example of graphical output by using current prototype system. This window represents traffic volume change in pedestrian network between before and after the policy described in Table1. It is confirmed that fairly many of links along bus route 2 are reducing its pedestrian traffic volume. On the other hand, some links' traffic volume surrounded by bus route 2 is increased. That is to say, travelers who use the bus route 2 change its route to these links. Figure 9 is another example snap shot of illustrative display showing the ratio of traffic volume to capacity as LOS in whole automobile network after the policy adoption.

These visualized result presentations are intuitive and comprehensible. This functional design, therefore, is very useful for transportation managing planning, policy development and evaluation.

Table 1. Traffic Volume and Travel Time of Pedestrian Links along Bus Route 2

(a) Before Policy Adaption

Link ID	Traffic Volume (P/h)		Travel Time (min)	
	1 -> 60	60 -> 1	1 -> 60	60 -> 1
1	0.000	9.388	0.765	4.302
3	33.701	35.781	1.373	4.382
7	251.069	68.648	0.947	4.009
11	340.585	188.279	0.661	3.717
15	100.134	709.404	1.257	1.257
19	649.499	497.648	0.765	1.283
20	245.511	11.514	0.597	2.986
38	138.370	1.493	1.792	1.792
59	227.384	202.671	1.530	1.530
72	169.397	169.725	1.080	1.392
70	10.623	156.932	3.616	1.101
68	338.792	52.055	0.661	0.661
66	15.632	42.134	2.127	0.650
64	110.906	11.450	1.153	1.153
63	206.145	37.286	0.344	0.338
60	5.049	198.127	2.259	0.713
Total	2842.795	2392.533	20.928	31.265

(b) After Policy Adaption

Link ID	Traffic Volume (P/h)		Travel Time (min)	
	1 -> 60	60 -> 1	1 -> 60	60 -> 1
1	22.712	8.746	0.765	4.302
3	38.031	16.012	1.373	4.856
7	179.617	51.901	1.965	4.009
11	191.503	192.055	1.079	3.717
15	121.434	645.736	1.257	1.257
19	537.674	407.889	0.765	1.403
20	226.509	7.858	0.597	3.359
38	105.826	4.272	1.792	1.792
59	253.763	146.716	1.530	1.604
72	133.985	105.981	1.080	1.934
70	6.546	114.807	3.400	1.101
68	288.965	43.634	0.661	0.661
66	1.703	33.087	2.786	0.650
64	52.300	84.534	1.153	1.153
63	159.512	34.106	0.348	0.338
60	6.290	340.975	1.946	0.713
Total	2326.370	2238.308	22.498	32.850

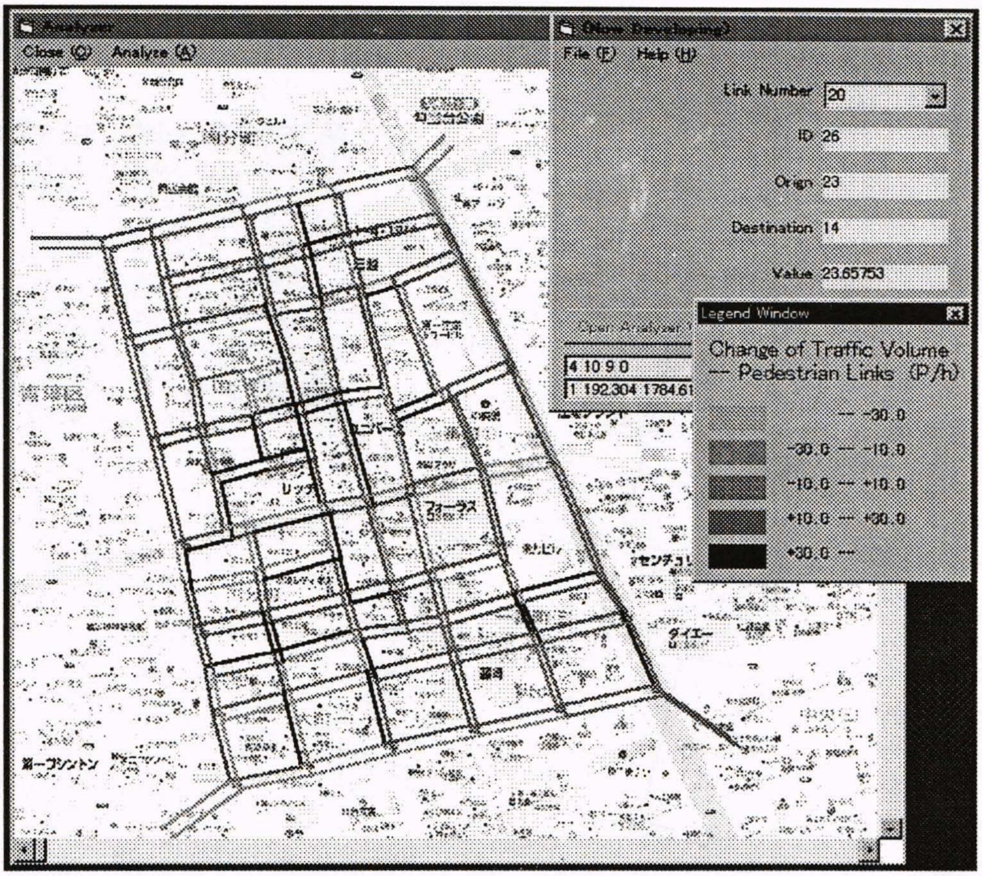

Figure 8. Illustrative Example of Current Prototype System (Change in Pedestrian Traffic Volume)

5. CONCLUDING REMARKS AND PROSPECT FOR THE FUTURE

The system design in this study targets to evaluate the effects of traffic management policies based on GIS platform. By a devised database design, it is able to represent the multi-modal network effectively. Also this system is capable of being used as evaluating tool for traffic management policies practically.

However, as noted above, some features are still on developing stage. Continued research on implementing and calibration of the elements and confirmation of model's theoretical consistency is required. In addition, we plan to improve further the database design and take a refinement of system.

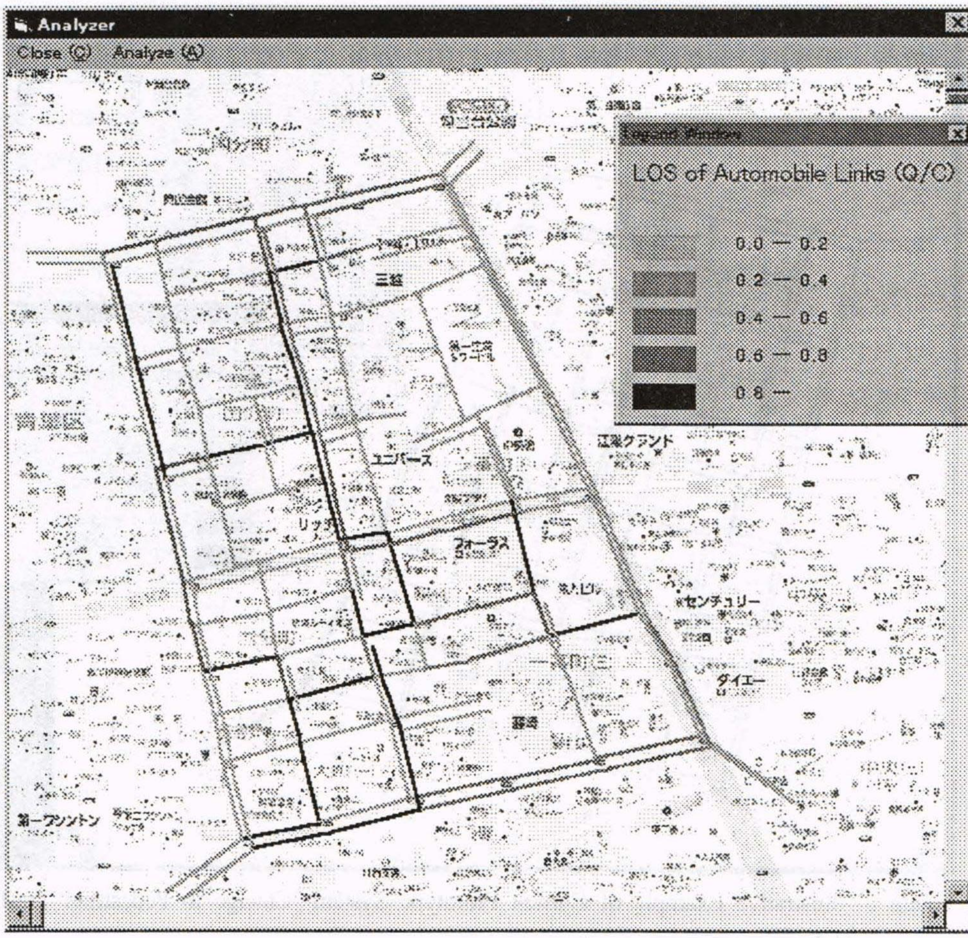

Figure 9. Illustrative Example of Current Prototype System (LOS)

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