TOWARDS A PC BASED DIGITAL ROAD MAP SYSTEM (DRMS) FOR METRO MANILA

Herculano FELIAS, Jr.
Graduate Student
Science University of Tokyo
Chiba, Japan

Hisao UCHIYAMA
Associate Professor
Science University of Tokyo
Chiba, Japan

INTRODUCTION

This paper discusses some preliminary work done towards the creation of a PC based Digital Road Map System (DRMS) for the city of Metro Manila. The system implements a two-level map system and has basic display and data management capabilities. It also provides some applications which support transport planning and traffic engineering work.

1. BACKGROUND

The importance of road maps is underscored by the large number of private citizens who refer to them in order to find out the relative locations of different places of interest. More importantly, road maps are fundamental sources of information to transport planners and traffic engineers. This is the primary reason why most of the developed countries today implement a Digital Road Map System (DRMS) in one form or another.

Often these DRMS's are sophisticated systems (usually implemented using mainframe computers) used in a variety of ways such as an information system, giving online data pertaining to traffic conditions, location of vehicles through satellite tracking etc., or are used as repositories of transport planning and traffic engineering data that can easily be accessed for general planning and engineering exercises like simulations, forecasting, and modeling. Needless to say, such sophistication entail equally sophisticated and therefore expensive hardware.

The importance and potential of these systems, as tools for traffic engineers and transport planners, justify at least, the consideration of whether to implement such a DRMS in a major third world city. However, substantial capital outlay for a true sophisticated DRMS, becomes a major deterrent in instituting such systems in less developed countries. Hence, there is the need for a simpler DRMS, which not only implements a possible subset of the functions found in more sophisticated systems but also configured to run in a relatively cheaper, possibly diskette-based PC environment.

This paper presents the results of preliminary work done towards the development of such a DRMS as applied to the city of Metro Manila.

2. METRO MANILA TRANSPORTATION NETWORK

The city of Metro Manila is actually a conglomeration of 4 cities and 13 municipalities. It spreads over a 636-square kilometer area extending about 50 km. from north to south and 20 km. from west to east. The transportation network is composed of a road network approximately 2,800 km. in length, a light rail transit (LRT) line, and a train service line operated by the Philippine National Railways (PNR).[1] Two future light rail transit lines are currently in the planning stages and are expected to be built and operated in the very near future. The city divisions and the overall configuration of the

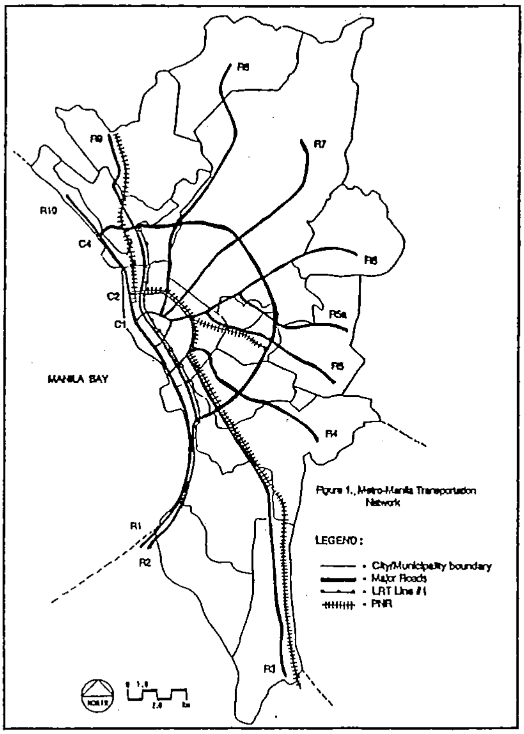

Figure 1. Metro-Manila Transportation Network

transportation network is shown in Figure 1.

This figure clearly shows that the city has the classic ring and radial road configuration. This road configuration has influenced the development of business and commercial areas particularly in the vicinity of the major radial and ring roads. The city landuse is predominantly of mixed residential-commercial type (especially within ring road C4) resulting in complicated travel patterns.[2]

Public transport comprise mainly of buses, jeepneys, the LRT and PNR services, tricycles, pedicabs and taxis. The total number of trips per day (in 1984) was around 14.8 million of which 24.6% used private vehicles and 75.4% used public modes. [3] The most dominat public mode is the jeepney, carrying about 54% of the total public trips and the rest being carried by bus, LRT, tricycles, pedicabs, and a very small percentage by PNR.

3. DIGITAL ROAD MAP SYSTEM

The functional structure of the Metro Manila DRMS is shown in Figure 2. The system is built around a database which incorporates the digitized road map, information related to different nodes and links, and other important transportation planning data. The DRMS provides basic data management functions (to manipulate the database) and has graphic display capabilities. The system also provides some subsystems which support transportation planning and traffic engineering applications. Since these applications have modular constructs, future applications can easily be attached as they are developed.

3.1. The Digital Map

The digitized road map data are based on standard Universal Transverse Mercator (UTM) projection maps (with a scale of 1:10,000) so stored node coordinatescan easily be adapted and used according to standard global positioning systems in the future.[4][5]

To create the digitized map, Metro Manila was divided into 119 grids of about 7.6 km^2 each as shown in Figure 3. These grids enable the grouping of the transport network nodes and links (and other pertinent information) into files which are not only of manageable sizes, but also of semi-independent nature in order to address the issue of data portability. In doing so, related files, for example, those that encompass a transport

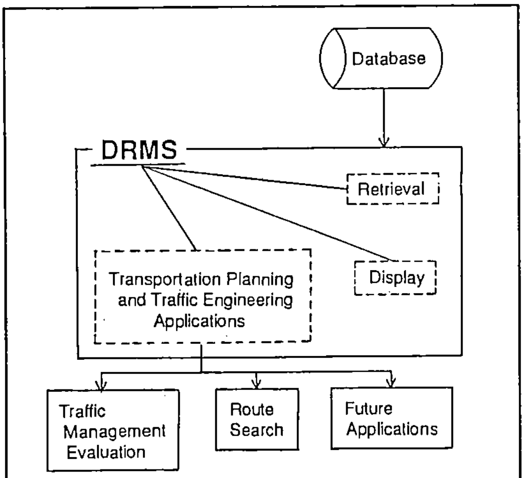

Figure 2. Functional Structure of the Metro-Manila DRMS

planning zone, can be easily grouped together and stored independently in separate diskettes (or other portable media).

Network data for each grid are digitized and stored in two separate files, each of which representing a different level of the the digital map. The first levelincludes preimary arterials used for inter-suburban traffic movement, and those used as routes by public transit lines. The second level includes all roads not included in the first level. These are in general, non-primary roads whose main function is to provide access from other non-primary roads or from abutting property to the first level network. The first level therefore, is the digitized representation of the overall Metro Manila network. It is however, stored as a collection of grids to properly define the scope of the lower level maps. This way each grid in the first level map automatically defines a corresponding lower level map which stores the details not found in the first level. The shaded grids in Figure 3 are those which to date, had beed digitized for the second levelnetwork. The two-level design of the digital road map therefore is achieved through a multi-scale approach. This way, applications requiring only the general form of the network may use only the higher level, while those requiring more network detail may use the lover level. This multi-level design of the DRMS is illustrated in Figure 4.

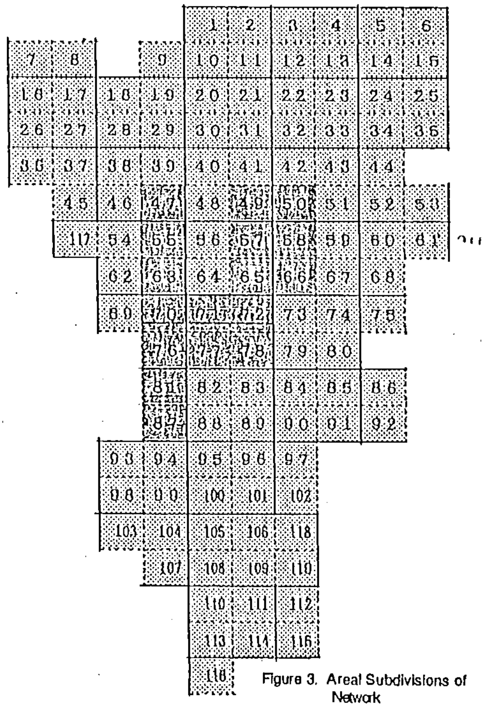

Figure 3. Areal Subdivisions of Network

3.2 The Database

The files that support the DRMS are designed to be transparently independent but these are actually interrelated by the node-, link-

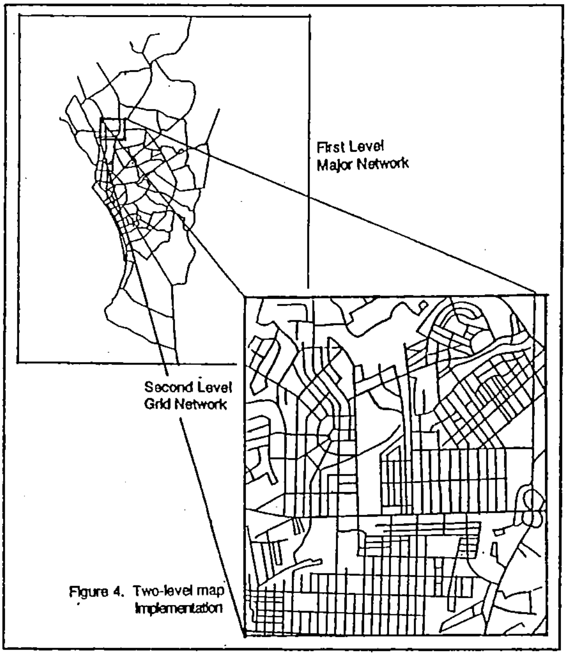

Figure 4. Two-level map Implementation

and area-indices. The collection of these files and their linkages form a relational database from which information for the display function and other application subsystems of the DRMS may be extracted. The different indices are used as linkages or paths in order to retrieve related information which are stored in different files. Figure 5 shows that each grid map is stored as three files; one to store node information, another to store link information, and a third to store the trajectory of the link. Other data available are intersection geometries and signal settings, OD tables, route trajectories, and landmarks. It also shows that the first level network, although conceptually one map representation of the major network is really composed of several independent files.

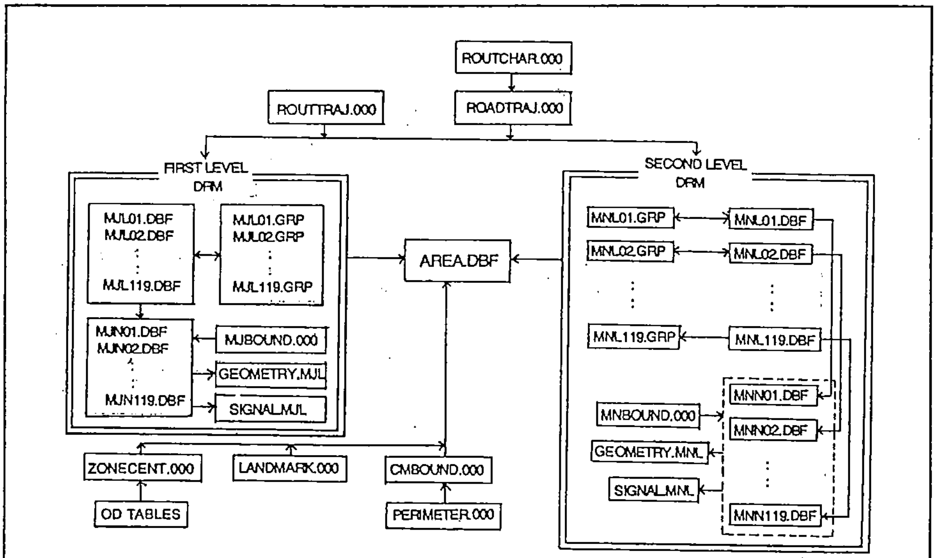

Figure 5. Metro-Manila DRMS Database File Linkages

3.3 Graphic Display

This DRMS function provides for the graphical display of most of the information stored in the database related to the nodes and links currently supported by the database. Nodes refer not only to network intersections but also to selected pedestrian crossing points, public transit terminals and train stations, and important landmarks.[6)7)] Landmarks refer to special point locations in the city such as hospitals, airports, government institutions, major department stores, embassies, hotels, etc. The DRMS can display the relative locations of such nodes and some related traffic characteristics (when applicable). For example, for network intersections, the geometry, capacity, peak flows, and signal parameters may be displayed. For transit terminals and train stations, boarding and alighting profiles may be displayed. In the case of landmarks, locations of all hospitals in the city, for example, may be simultaneously displayed in order to get an overall picture of their relative positions. In addition, information on households will incorporated in the database, e.g., names of household owners, addresses, household socio-economic characteristics, etc., in the future.

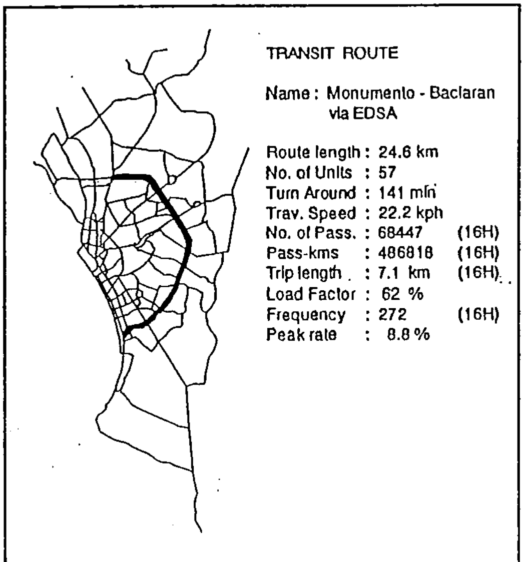

Figure 6. Transit Route Information Display

Links, on the other hand, refer to a single connection between two network does (a road segment) or a group of links forming a trajectory. This way, single links may be selected so that their relative location in the map and some attributes such as peak hour volumes, link width, number of lanes, etc., may be easily displayed. Groups of links may be selected for example, to trace the trajectory not only of a specific road but also of a route used by public transit lines. In the latter case, line frequencies, headway, etc., may be displayed. Sample graphic output formats are shown in Figures 6 and 8.

4. DRMS APPLICATIONS

4.1. Route Search

This application module provides a search and display function for the trajectory of the minimum path between an OD node pair.The OD nodes may be selected from the intersections in the major network or may be specific landmarks. The minimum path search basically uses Dijktra's method applied on the combination of the multi-level network. This is under the assumption that road users procedd according to the following general travel pattern, i.e., they leave the origin node, use secondary roads around the

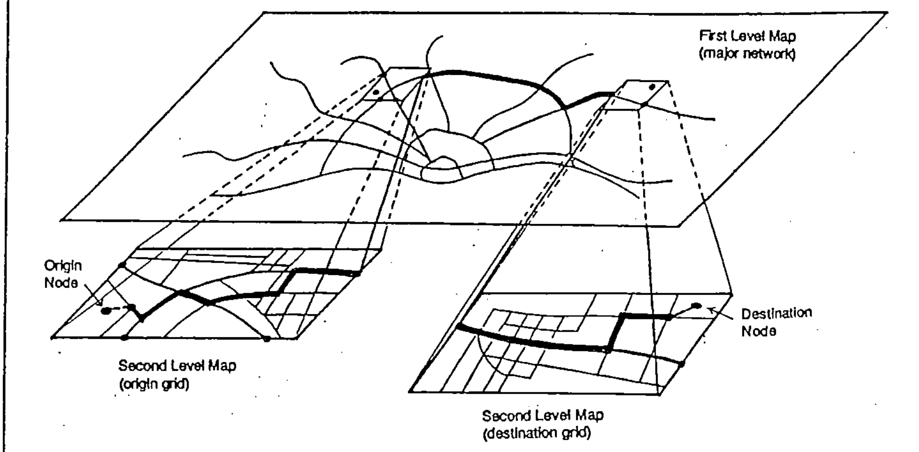

Figure 7. Two-level Map Implementation of Route Search

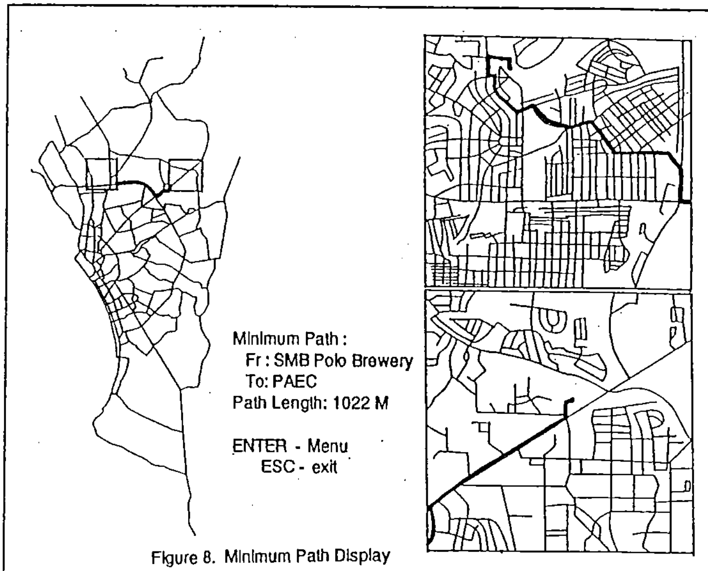

Figure 8. Minimum Path Display

periphery of the origin node to access the major network, proceed along a perceived minimum path, using major links, until a certain area is reached where again, secondary roads are used to access the destination node. This process is illustrated in Figure 7 and a sample graphic screen is shown in Figure 8. The minimum path search algorithm therefore, uses secondary roads (in the second-level map) in the grids where the origin and destination nodes are found and uses the first-level map in areas outside these grids. This module, if installed in strategic places, e.g., bus and jeepney terminals, LRT stations, gasoline stands, etc., can function as an information systemto serve the general public. It may also function as the core of an auto navigation system[8] (given the proper hardware) if installed in vehicles.[9]

4.2 Traffic Management Scheme Evaluation

This application module provides for the analysis of a planned traffic management scheme to be implemented in a particular study area within the scope of the digital map database. After identifying the area scope of the study area, the nodes encompassing the area are extracted from the database to form a subarea (or focused) network. Unnecessasy nodes and links are then filtered out, additional nodes and links are added, node/link attributes (e.g., capacities, QV characteristics, percentages of turning movements, etc.) are edited depending on the different traffic management scenarios to be tested. Simulation results are then compared in order to select the best way the planned traffic management scheme should be implemented. This module was used to test the impact of different one-way implementations on a simple network around Metro Manila's Ermita area, one of the cities busier commercial districts.

4.3 Future Applications

The DRMS is designed to easily incorporate other modular applications which are planned to be added in the future. One application being considered is the use of the DRMS to help in automating the process of generating the LOS data of particular transit routes (a difficult task considering the complexity of transit operations in Metro Manila). Another is the preparation of possible route alternatives for the purpose of disaggregate behavior modeling. These applications are already in the pipeline and hopefully will be operational by early 1993.

5. NETWORK SIMULATION USING THE IO METHOD

The network simulation module used by the Metro Manila DRMS is based on the Input/Ouput (IO) method, a simulation model developed by the Tokyo Metropolitan Expressway Public Corporation.[10] The original purpose of this method is to simulate vehicular flow in expressways, where the target network is an open network with defined ingress and egress nodes.

5.1 IO Method Basic Principles

Figure 9 show a simple open network which is used to explain the basic principles behind the IO method. In this figure, nodes A and B are ingress nodes, E and F are egress nodes, C, a merging node and D, a diverging node. The input data for the simulation are input flows in the ingress nodes and output flows in the egress nodes recorded at regular intervals (usually taken from detector data) and average turn rates at the merging and diverging nodes. Within each increment of the simulation period, two calculations are done, the first (called upstream calculation) computes the link densities, volumes, and travel times on each link, and demand and output flow on each node based on the values computed from the previous increment.

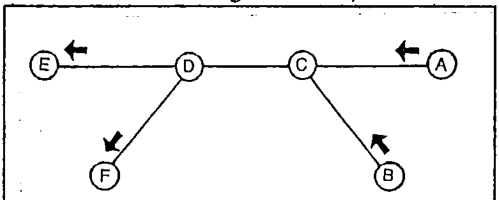

Figure 9. Input/Output Method Applied

During this process, the model determines the demand on each junction (those that need to exit the node) then using junction capacities, determines how many vehicles could not be served during the simulation increment. These vehicles are said to be backed up on their current links. A second calculation (called downstream calculation) is then performed to compute the queue lengths on links where backed up vehicles exist. During the calculation process, backed up vehicles may stay at their current links (if link capacities allow) or may overspill to backward links. In Figure 9, for example, backed up vehicles on link C-D may overspill to links A-C and B-C.

5.2 IO Method As Applied by the DRMS

It should be noted that with the above simulation setup, vehicles diverging from the main network trunk in fact, ultimately leave the simulation system, which is not the case in a closed network. In order that the DRMS module may apply the IO method principles to a closed network, some simplifications were used. First, trees from all ingress nodes were generated, where the root of a tree corresponds to the ingress node and terminal nodes correspond to all possible egress nodes. Such trees represent all possible paths from the ingress node to all egress nodes. An example of such tree is shown in Figure 10. Second, the trees are "pruned" to retain only logical paths. (In Figure 10, one such "illogical" path is 1-2-3-7-6-2-8). Finally, within an increment of the total simulation time, each path in a tree is traversed with flows at jumctions divided according to the percentages of the turning movements.

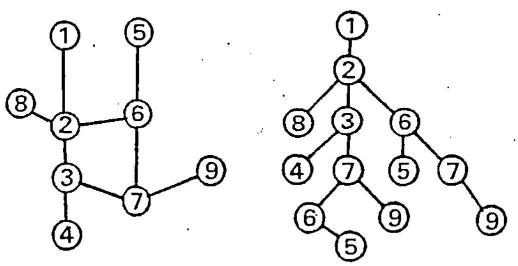

Figure 10. Sample Network and Tree Concept

Some major departures from original implementation of the IO method are as follows. Since the DRMS implementation of the the IO method is based on the above-mentioned tree concept, there is the possibility of a link being scanned several times during the simulation period (note the multiple use of links 6-5 and 7-9 in Figure 10). Backup calculation in the original implementation proceeds from the main trunk exit down to the main trunk entry node. In the DRMS implementation, backup calculation is based also on the tree structure of possible paths, thus overspilling vehicles are carried up the tree along the path currently being considered. For example, the backup process for path 1-2-6-5 in Figure 10 proceeds along the reverse direction, i.e., 5-6-2-1. The backup process however, pauses at a tree junction and attempts to redistribute the vehicle overspill to other branches before proceeding to the root node, hence the overspill at link 5-6 is first attempted to be loaded at link 6-7, the excess carried up to node 2, again redistributed to link 2-8, and finally carried up to root node 1.

Unlike in expressways where all vehicles entering the "system" ultimately exit via some egress point, such is strictly not the case in the open networks for which the DRMS simulation module is intended to be used. This is because the final network to be used by the DRMS module will usually be a simplified network, i.e., some minor links might have to be deleted, links which however minor are possible entry or exit links. In addition, some vehicles might terminate or begin between two defined nodes. To take these into account, the DRMS module defines some source and sink factors for each link which are iteratively changed during model calibration.

5.3 Network Simulation Case Study

The DRMS traffic system management simulation module was tested using the network shown in Figure 11 which show a simplified network (only major links) of Ermita, one of the busier commercial areas in Metro Manila. Although detector data were available in all the entry and exit nodes, only 6 out the possible 14 links had detector data which were available for model calibration. Ordinary least square analysis between link volumes of the calibrated network against the available detector data show a rather low R^2 coeffecient (0.582). It is felt that more detector data may lead to better network calibration since this simulation module was likewise tried in two small case studies in Japan (Kashiwa and Matsudo, Chiba) where OLS R^2 factors of 0.87 and 0.98 respectively were recorded.[11)]

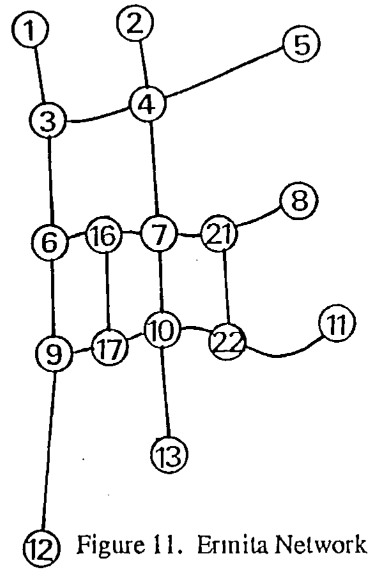

Figure 11. Ermita Network

The traffic management schemes that were tested after the network was calibrated pertain to one-way implementation on link pair 16-17 and 21-22. In the first scheme, link 16-17 was made one-way northbound and link 21-22 made one-way southbound, i.e., clockwise (CW) implementation; the second case is counter-clockwise (CCW) implementation.

The comparative overall average network response, i.e., averages for all links, is shown in Table 1. Comparing these three cases show that implementing a one-way scheme for the abovementioned link pairs will lead to better network performance and that the clockwise implementation is best.

	Speed(kph)	Density(vpk)
Base	23.0	142.9
CW	25.0	138.5
CCW	24.5	143.1

Table 1. Comparative Case Responses

6. SUMMARY

The DRMS described, is at best in its skeletal form, though as is, it performs the basic functions it was designed to do. The database as yet, is not complete but is continually being updated. The digital road map is based on the latest available maps released in 1987 which are expected to be updated, at the earliest in 1997. The digitized network stored in this DRMS can easily be updated in order to cope with or reflect the changes in the transportation network as they occur until the next series of base maps are published. This way the DRMS remains current and its subsystems not dependent on old published maps.

In its present form, the DRMS simulation module has no information on vehicular OD, hence with the tree implementation of the IO method, flows entering ingress nodes are distributed along the tree paths until they exit the network via the egress nodes. This distribution is currently simply implemented using average turning movement percentages. Thus, the module must be further improved by adding perhaps a route selection model. The source and sink factor generation must be improved by perhaps some trip generation/attraction model on a microscopic scale.

The main thrust of the succeeding endeavors towards the finalization of this system at present, is the completion of the database system but studies are being continued in order to improve the current subsystems being implemented and in order to add more subsystems which can support transportation planning and traffic engineering in general in the future.

BIBLIOGRAPHY

1) JUMSUT Report : Metro-Manila Transportation Planning Study. Manila, 1984, 1985.

2) Felias, Herculano,Jr. and Sasaki,S.. Analysis of Metro Manila's Trip Demand Structure Based on Characteristics Determined by Zonal Socio-Economic Variables. Planning Administration, No. 29. Japan Association for Planning Administration. 1991.

3) Nakamura,Ryuiji, and Kashima, S.. The Basic Study on Mode Choice Characteristics in Metro Manila. Proceedings of the 5th World Conference on Transport Research, Vol. 3. Yokohama, 1989. pp. 657-670.

4) Parkinson, B.W., et al. NAVSTAR : Global Positioning System-Ten Years Later. Proceedings of the IEEE, Vol .71, No. 10. 1984. p.1177.

5) Payne,C.R.. NAVSTAR Global Positioning System:1982. 3rd International Geodetic Symposium on Sattelite Doppler Positioning. 1982. p.993.

6) Nakamura, H., Hayashi,Y., Miyamoto, K.,and Uchiyama,H.. Computer Aided Transport and Landuse System (CALUTAS) for Evaluating Infrastructure Planning. Proceedings of the 4th World Conference on Transport Research Vol. 1. Hamburg. 1983. pp. 620-633.

7) Seetharam, K.E., Shibazaki,R., and Nakamura,H.. Integration of Geographical and Expert Systems for EIA in Urban Transportation Planning. Infrastructure Planning Review. JSCE. 1990. pp. 281-288.

8) Kawamura,S., et al. Development of Navigationational Equipment for Automobiles.Jidosha Gijutsu, Vol. 39, No. 5. 1985. pp. 525-531. (in Japanese).

9) Seymour,H.R.. History of Automatic Vehicle Monitoring (AVM). IEEE Transactions on Vehicular Technology, Vol. VT-26, No. 1. 1977. pp.2-6.

10) Metropolitan Expressway Public Corporation (Report). A Study on Information System Methods. Japan Society of Traffic Engineers. March 1988. (in Japanese).

11) Saitoh, Y.. A Study on the Effects on Area Control of Intersection and Network Flows. Unpublished Master Thesis. Science University of Tokyo. 1992.