COMPUTER-AIDED DESIGN IN LOCAL STREET
PLANNING AND MANAGEMENT

Michael A.P. Taylor
Department of Civil Engineering
Monash University

ABSTRACT:

Local area traffic management has emerged as a major concern and area of activity in Australian traffic planning, and a planning methodology for use in traffic studies is emerging. This paper describes the relevance and application of procedures from the new information technology, especially computer-aided design (CAD) in the planning and management of local street networks. The procedures are shown to offer traffic planners new and perhaps more appropriate means for using computers in their work. The application of CAD in a local network traffic model is used as an illustration.

INTRODUCTION

In the urban Australia of the 1980s, community concerns about traffic movements in local areas have become of special importance to local government, regional and state authorities, and their transport planning and engineering advisors. In this area, recognition of the existence of a problem and the desire to solve it are not sufficient, for it is the course of remedial action that presents the main difficulties. The choice and implementation of solutions to local area traffic planning problems are themselves significant problems (Brindle 1984).

The 1980s also present us with the products of the "information revolution", notably the developments in microelectronics, the decentralization of computing power, and the evolution of "knowledge engineering". To the transport planner, the impacts of these products may be seen most clearly in the growing use of personal computers for both general applications (e.g. wordprocessing, spreadsheet analysis, statistical analysis, database management) and specialized tasks (e.g. microcomputer versions of transport and traffic planning models), and the concomitant spread in the availability of these productivity enhancing tools. This is particularly relevant to the small planning offices which characterize consultancies and local government.

This paper is concerned with the ability of the new knowledge-based procedures (such as interactive graphics, computer-aided design (CAD), and "expert systems") to assist transport planners in addressing the problems of modern urban society. The example of local street planning and management is used to illustrate some of the possibilities. An important point is that although these knowledge-based procedures have been developed for use in other areas of professional and technical expertise, they stand to make significant contributions within the transport planning sector. A particular focus of this paper is on the potential role of CAD in local area traffic management, with an illustration of how the new technology may fit in with the human side of traffic planning to a far more satisfactory degree than other computer-based methods.

At the heart of this discussion is the recognition of an evolutionary path in the development of traffic planning models. For the author this is largely a matter of personal recognition. Consequently this paper moves from the general to the specific consideration of particular models for use in local area traffic management. The reader is asked to forgive this indulgence, perhaps by noting that this mechanism does allow a sound appreciation of the usefulness of the "new" procedures. Attention may be directed to four main areas of interest :

(a) improving the efficiency of data input to transport planning models;

(b) allowing model users to view the workings of a particular model;

(c) providing new means for the interpretation of transport data, and the distributions of data variables across a study area; and

(d) providing new means for community participation and involvement in the planning process.

The paper considers these four areas in the context of local area traffic planning, i.e. the consideration of problems in planning and design of local street systems and their connections to the arterial road system, to cope with localized traffic demands and traffic/environmental impacts. This is done by considering firstly the importance of local area traffic management in Australian cities, and then the existing means for computer assistance in tackling these problems. The role of new information technology in this process is then discussed, and the application of specific aspects of the new technology is described.

IMPORTANCE OF LOCAL AREA TRAFFIC MANAGEMENT

A major development in traffic planning over the last decade has been the growing concern for, and importance of, local area traffic management (LATM) in urban areas. The responsibilities for LATM are widely diffused, and the local government sector has a frontier role. There are difficult problems to be resolved, largely because of the multiple and sometimes conflicting objectives to be considered. A need for systems-based planning procedures and models is apparent. For example the multi-variate nature of local area traffic encompasses a wide range of factors, including :

(a) traffic movement (e.g. flows and speeds);
(b) physical layout of areas;
(c) behavioural characteristics of road user groups (e.g. children, drivers);
(d) topological layout of street networks;
(e) social and economic factors relating to the resident, business and workforce populations of an area;
(f) institutional influences and methods for the implementation of traffic plans;
(g) environmental influences, including air, noise and visual pollution;
(h) traffic safety and perceptions of danger; and
(i) levels of accessibility and mobility within and through an area.

This is not an exhaustive list of factors, but even so it is extremely broad and includes a number of interacting and possibly contradictory factors. Planning policies based on a single factor (or even a small group of factors) which do not consider possible side-effects are likely to fail. Evidence for this assertion was provided in a review of local area planning initiatives in the Melbourne region reported by Taylor and Newton (1981), where it was found that although most of the municipalities and authorities surveyed saw similar problems, (e.g. a concern about °excessive° traffic in residential streets), their responses were widely different, even across adjoining municipal boundaries. Some agencies were prepared to try a variety of new management measures, while others, with equal concern about problems, adopted a more conservative stance on the grounds that measures to improve conditions in one street might only worsen conditions elsewhere. The system effects of incremental changes to a street system were of concern.

Further evidence found by Taylor and Newton (1981) was the evolution of local area traffic planning during the 1970s, from initial measures involving physical street closures, largely uncoordinated, to measures aimed at solving problems resulting from the combination of factors listed above (e.g. speed and partial access restrictions using systems of roundabouts, humps and narrowings, and complementary measures to improve arterial road flows). Again the traffic system was a major concern. Safety issues in local areas further support the need for a systems approach because accidents in such areas are widely diffused (Brindle 1979, OECD 1980) so that the systematic application of area-wide design and remedial procedures is required. More recently Brindle (1984) reviewed the current state of practice and suggested that too much attention was being directed to the use of control devices (the physical elements of a traffic plan) and that insufficient attention was given to a holistic appraisal of LATM.

This perspective of local street planning issues is still largely that of the local community and municipality, and it must not be forgotten that there are other valid viewpoints. In particular the views of the regional transport/traffic authorities who have responsibilities for metropolitan arterial road systems, and the users of these networks are also important. The balance between the arterial road and the local street systems may be crucial in the overall efficiency of the road transport system, so that tradeoffs between the objectives and desires of the various parties must be recognized.

Means to help resolve these possible conflicts have been sought for a long time, and the possibility for using computer models in the screening and evaluation of proposed traffic management schemes has long been considered (e.g. Taylor 1978). Until the advent of the new information technology the practical use of these techniques was fairly restricted.

USE OF COMPUTERS IN LOCAL AREA TRAFFIC MANAGEMENT

Definition of a Local Area

A local area may be taken as a small part of an urban area, of the order of perhaps one square kilometre in area, and corresponding to a limited number of °traffic cells° (i.e. areas in which the function of the street system is primarily to provide access to properties. In the street network for this area, a planner may want to distinguish between :

(a) different classes of roads and streets;
(b) various design standards for streets;
(c) different intersection controls;
(d) turning and through movements and intersections;
(e) lane configurations at intersections;.
(f) classifications of vehicle types; and
(g) classifications of trips (such as through or local traffic).

Models of Local Area Networks

There have been many attempts to use computer-based tools in LATM, from the early 1970s onwards (e.g. Stephens and Cox 1972, Giannopoulos 1973, Wigan 1975, Taylor 1977), and presently represented by traffic network models such as CONTRAM (Leonard, Tough and Bagley 1978), SATURN (Hall, Van Vliet and Willumsen 1980), and MULATM (Taylor and Hatjiandreou 1984). These tools are the descendants of the traffic assignment models used in urban road network planning. Their main distinguishing features from their ancestors are an ability to model the growth and decay of congestion and queueing in street networks, and a need to model delays and capacities at junctions (network nodes). The study networks are characterized by a general one-to-one correspondence between the links in the network and the street sections in the area.

Until recently, the widespread use of these models, for instance at the local government level, was restricted. The models existed only on large mainframe computer systems, and were not readily accessible in practice. Further, model users required special training and experience in such facets as network coding. The data preparation tasks were arduous, and fraught with difficulties. Errors were easy to make and hard to trace. Once a network was established, it was fairly difficult and time-consuming to make incremental changes to it, so that users had only restricted opportunities to test alternative schemes. In part this was due to the difficulties in preparing and coding network data. It was also due to the °batch-mode° operation of most of the models, which prevented the user from controlling or intervening in the actual model run.

The theme of this paper is how the advent of interactive graphics and CAD systems on microcomputers can relieve these difficulties, and may permit the far wider use of these models by the people directly responsible for implementing local area traffic plans.

Database and Network Inventories

An essential element in local street planning and management is the consideration of the micro-level interactions between the traffic system and the land use system. Largely this involves the comprehension of the land uses and developments in the study area, including factors such as traffic generation characteristics, architectural features and styles, and population characteristics. For the traffic system, inventory data on the state(s) of the street network are also needed (e.g. the numbers and locations of traffic control devices and intersection types, or the distribution and availability of car parking spaces). In the past the needs for these inventory data were met by manual methods (e.g. Loder and Bayly 1974). However microcomputer packages now offer powerful means for assembling, editing, storing, analysing and disseminating these data. For example Anderson and Taylor (1984) described the use of database and mapping programs for analysing and displaying local area data. Such applications are but one outcome of the new information technologies which will be of great value in transport planning.

ELEMENTS OF INFORMATION TECHNOLOGY

Microcomputers

Arguably the seed of the information revolution was the microprocessor. This permitted the wholesale miniaturization of computer components, and from this came the ability to produce small, cheap, robust computers which can be widely distributed, used under a range of environmental conditions, and yet have similar conceptual capabilities to large computers, without the attendant needs for specialized support services. Coupled with the microprocessor have been developments in data storage and display devices (e.g. floppy disk drives, miniature hard disk drives, high resolution colour video screens) which when put together provide powerful and compact personal computer systems for data entry, analysis and modelling.

These systems permit the general use of powerful, sophisticated software packages which previously could only be run on mainframe computers. In many instances (e.g. commercial applications such as wordprocessing) this gives the first practical opportunities for the use of advanced techniques in the real world.

Software Developments

There has been an explosion of program packages for use on microcomputers. Initially these packages were directed at commercial and business markets, and more recently towards professional and technical applications. Specialized packages for particular tasks (e.g. traffic impact analysis) are now emerging. A number of successful seminars and workshops were held in Australia during 1984, to demonstrate the possible transport planning applications of of these new packages. For example, seminars were held at Monash University (February 1984), and by Pak Poy and Kneebone Pty. Ltd. in Melbourne and Sydney (October-November 1984).

Some important terms need defining :

(a) a computer package is an applications program or set of programs available as a self-contained unit, with accompanying documentation, and able to perform a set of tasks nominated by the user. There are further subclasses of packages as indicated below;

(b) generic packages are packages capable of use by any individual, independent of experience or expertise, such as wordprocessing. These packages permit users to improve the productivity of tasks they may be already performing (such as report writing); and

(c) functional packages are packages that perform specific tasks connected with a particular organizational function (e.g. payrolls, stock inventory, or traffic network analysis). Most computing in the past was performed with functional packages.

Although the specialized nature of traffic planning and traffic analysis sets requirements that are primarily functional, there are procedures available in the generic packages which are particularly useful in traffic studies. This recognition by the transport and traffic planning fraternity will lead to improved productivity and quality of work. Young and Taylor (1984) discussed the relevance, advantages and use of micro-computer-based statistical packages in transport planning, and their paper provides an example of the productivity gains which may be realized. Generic packages such as spreadsheets, interactive graphics and CAD procedures have great potential for traffic planning, as illustrated in the remainder of this paper.

Spreadsheets turn the computer screen into the equivalent of a large table, with rows and columns, like the spreadsheet pages used for accounting and bookkeeping. The computer is instructed to take the numbers contained in particular elements of the table, and perform calculations on them in a prescribed manner. Many calculations can be done very quickly, and the effects of changes to some elements on all others can be quickly determined.

Graphics programs convert numbers into pictorial form, and provide screen displays from which the user can gain greater appreciation of his/her data than is possible by consulting tables of numbers. Graphics also has an important part in the analysis of the operation of models, and in the input of data for models (e.g. Taylor, Hatjiandreou and Anderson 1984).

CAD systems are used for the automatic production and alteration of detailed plans and designs. As such they combine elements from database management, spreadsheets, graphics and artificial intelligence, and offer improved productivity for the design office. In the past they were the province of large organizations in industries such as aerospace and motor vehicle manufacturing, largely because of their expense. Microcomputer versions have now increased the general availability of CAD systems, and permit their use in smaller organizations. Wegener (1984) estimated that civil engineering and architectural design offices could expect realistic productivity improvements of between 200-300 per cent over manual systems. In the context of this paper it is the application of concepts and procedures from CAD systems into traffic network modelling, rather than the CAD systems in toto, which is important. This is demonstrated in the next section.

APPLICATIONS IN LOCAL STREET PLANNING AND MANAGEMENT

Three observations about the practice of traffic engineering may be made to start the discussion on the specific application of CAD in traffic planning :

(a) traditionally traffic engineers and planners have used graphical media. Maps and diagrams of street systems and detailed designs have been the standard means for communication;

(b) some of the pioneering work in the application of computer graphics was attempted in the traffic planning area (e.g. see McKerral and Dutton 1972); and

(c) in more recent times attempts to introduce computer-based procedures in traffic planning led to the adoption of other methods of representing traffic design data based on digital input.

Interactive graphic/CAD procedures now offer planners the opportunity to use the greater availability of computers in their work, without the difficulties of translating data between graphic (analogue) and digital forms. They can increase the productivity of planners by providing new methods for displaying and analysing the complex outputs of traffic models (e.g. traffic flows, delays and queues over a street network) and by providing means for the fast and reliable compilation and editing of input data sets. Previous methods have been time-consuming and complicated, requiring users not only to have some background in traffic planning, but also to gain expertise in computer operations and perhaps in some esoteric specialist areas of network coding. These needs have been major stumbling blocks in the use of computer models of traffic systems. The CAD methods remove the need for expert computer knowledge, and can be tailored to meet the express needs of the engineer or planner in a design office. Graphical displays are integral parts of the system, and many of the editing and display functions can be based on graphical techniques. For example, a street closure becomes the removal of a link in the network, and graphically this is done by erasing the line representing that link on a map of the network. The program then performs the file manipulations to register the change. This offers greater efficiency and accuracy than previous methods.

The specific illustration of this methodology may be seen in the development of the MULATM microcomputer package for local area traffic modelling. Three broader goals were set in this development :
(a) to encourage the use of computer methods in engineering and planning practice so that productivity may be enhanced and so that the latest techniques may be quickly introduced into practice;
(b) to encourage the diversification and decentralization of computer methods within the transport engineering and planning arena by presenting transport professionals with software designed for personal computers: and
(c) to illustrate the use of graphics as aids in the preparation and editing of complex data sets and in the interpretation and analysis of observed and modelled data.

The MULATM Package

MULATM is a traffic planning tool for use within the design office. It is derived from a mainframe version (LATM) which has existed for some years. Mainframe packages have had limited applications outside large authorities and research institutions, largely because practitioners have not had sufficient knowledge and experience to run them, and because the packages require large and complex data sets (descriptions of the spatial, physical and traffic characteristics of an area) as input. Compilation of these data sets is fraught with error traps, and errors can be hard to find in the later modelling process.

The mainframe packages have usually been used in a °batch° mode, requiring the construction of numerical data sets to describe networks. The data files are constructed separately, then used as inputs to the model. The user is often expected to learn special codes to describe particular data items, and this information is typically contained in extensive user manuals. The resulting data files are difficult for a user to interpret, and errors are hard to trace.

It should also be noted that these data constructions are unnatural devices for users. Traffic engineers commonly work with maps and diagrams, so that these media are more natural means for data entry. Graphical methods are particularly apt for traffic data assembly. Map displays of street maps and junction layouts enable the data elements to be checked simply and quickly. A logical extension is that CAD methods may also be used to edit network data, by providing fast and efficient means for adding and removing links, and offering visual checks of spatial configuration.

Microcomputer Graphics

Personal computers with interactive colour graphics offer the planner/engineer a significant opportunity to overcome the difficulties associated with earlier traffic model packages. Interactive programs for data input and model output greatly simplify and expedite the data preparation, and permit a wide range of informative displays using colour graphics on a video screen. Graphics may then be used in the design process as well as in analysis. Programming languages on personal computers (such as °GW-BASIC° on 16-bit microcomputers) offer inbuilt commands for rapid drawing of lines, points, polygons and arcs, for changing display colours and palettes, and for filling arbitrary (closed) areas with colour. This is all possible on a desktop (or even portable) self-contained computer system.

Interactive Data Input

The MULATM system was designed for use by people with little computer programming experience, but with a background in traffic engineering and analysis. The system operates through a series of display menus, and asks the user to provide the required network and traffic data interactively. Initially a network layout must be defined. MULATM offers the user a choice of digital input, specifying node coordinates and then nominating the sequence of nodes along each road, or a CAD procedure (not unlike the LOGO programs now widely used in computer education) in which the user draws the network on the screen and the program then automatically digitizes the drawing and stores the data on file. This is a particularly effective and efficient division of labour between man and machine. Layouts of road junctions are then presented in graphical form, and MULATM constructs the full details of these layouts on the basis of the user°s responses to series of prompts. Figure 1 shows an example. A small map of the street network is drawn, and the junction is highlighted so that its position may be seen. A diagram of the junction is given, with each leg identified by a number and its street name. Data are required for each leg in turn (e.g. if there are traffic signals at the junction, the cycle time for the junction, the green time and any phasing arrangements on each leg are required). The display highlights each element by colour. Link and node numbering is transparent to the user, and is performed by the programs. Users refer to links and junctions (nodes) by their street names, a human-based labelling system!

The MULATM package has some intelligence and can edit responses to check their validity. It only asks for essential information from the user, and makes use of previous information to minimize errors and inconsistencies. For example in Figure 1 the cycle time would be requested for leg 1, and then taken to apply to all other legs. Logical checks on green times and cycle time are also made. The user can check the display of the final layout before they are accepted in the input data. Colour graphics is particularly useful in highlighting the details in this process.

Once a °base-case° data files is established, alternative plans may be considered by editing this file, using interactive graphics displays to locate the relevant network components.

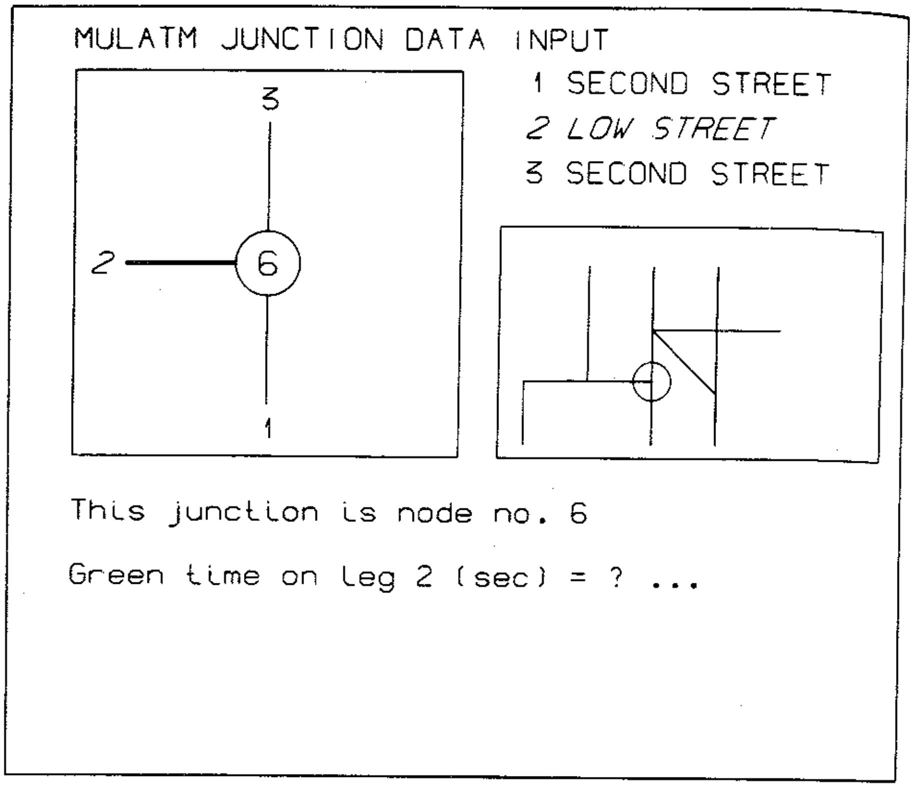

Figure 1. Junction Data Input in MULATM using Interactive Graphics

Displaying Traffic System Data

Model outputs (e.g. traffic flows, queues, travel times and delays) may be displayed on colour maps of the network, or analysed and presented in summary distributions and graphs. Colour screen displays provide fast, cheap and comprehensive information about alternative designs and comparisons between them. Area-wide distributions of parameters and variables such as road type, traffic flows, or queues can be quickly appreciated. The interactive CAD capabilities of the package enable map displays to be altered or highlighted as desired, through the use of °windowing°, translation and rotation procedures.

Windowing may be used to highlight a particular sub-area within the network. In the extreme this reduces to the display of an individual junction. Information on turning movements at junctions is basic information in traffic engineering. A display program is available to give this information from the model output, or from a database of observed traffic data. A junction diagram is drawn on the screen and each leg is labelled (Figure 2). The matrix of turning movements is displayed, and the user is given a menu from which he/she may choose to highlight the required elements and identify each

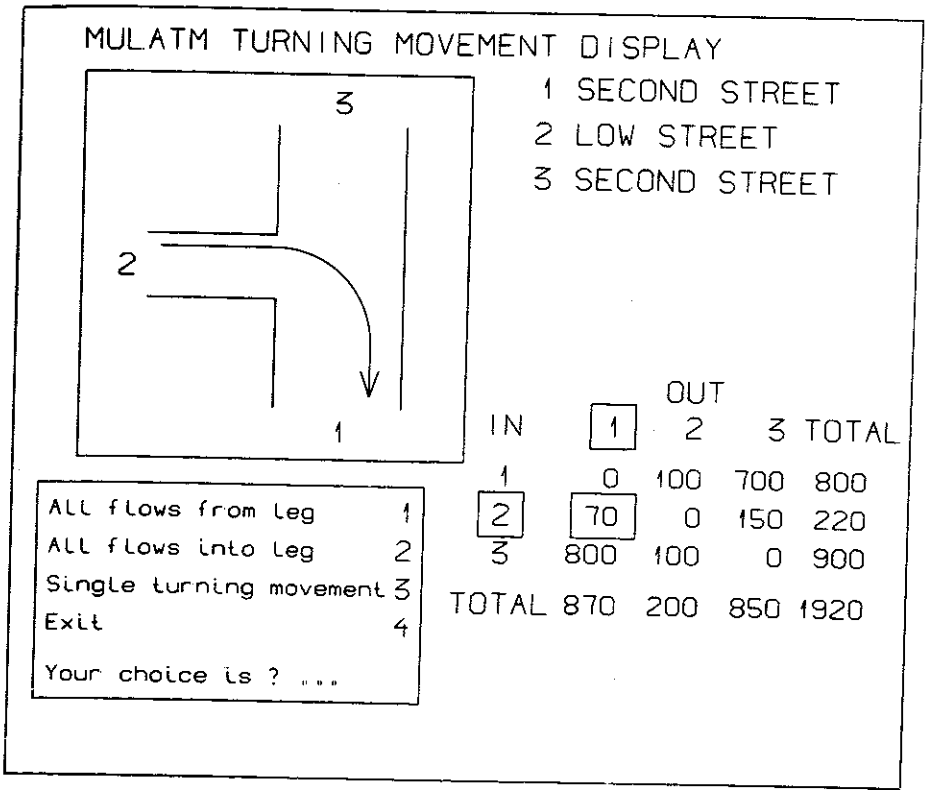

Figure 2. Interactive Display of Turning Movements

movement on the junction diagram. This procedure offers a convenient means for tapping traffic databases beyond its application in MULATM.

Observing Model Operations

A further use of the CAD procedures in MULATM is the display of the workings of the traffic model itself. Gipps (1983) described the use of interactive graphics to validate the operation of traffic simulation models. Interactive graphics may also be used to reveal model and traffic behaviour. For example Figure 3 is a static facsimile of a animated colour screen display which shows a "best" path for a particular trip through a local street system, given the traffic conditions and controls. The path is highlighted in Figure 3 by representing its links as dashed lines. In the screen display the path is identified by moving colour changes along the path. The model user may then vary network configuration (e.g. turn bans, closures or speed control devices) or traffic conditions (e.g. flows at other times of day), and then view any changes to the path selected for the trip. This permits a rapid examination of the likely effects of control measures, and yields an appraisal of their effectiveness.

There are further applications for such procedures in the community participation phases of a local area study, to explore the possible effects and outcomes of alternative schemes. Indeed techniques of this sort, mounted on portable microcomputers, may be useful aids in the direct involvement of residents in traffic planning for their locality.

CONCLUSIONS

The escalating power and availability of microcomputers offer transport planners and managers an exciting and effective means for improving their productivity and quality of work. The developments outlined in this paper, notably in the use of interactive graphics and CAD methods in traffic modelling and planning may be taken as indications of the new possibilities given to planners by the information revolution. The procedures provide a powerful and cheap means to bridge the various communications gaps between computers, planners, and the community. The practitioner now has the opportunity to use and develop the techniques previously only available to research groups with access to large computer systems. This offers the potential for increased productivity, improved satisfaction and quality of designs, and enhanced public participation in the planning process.

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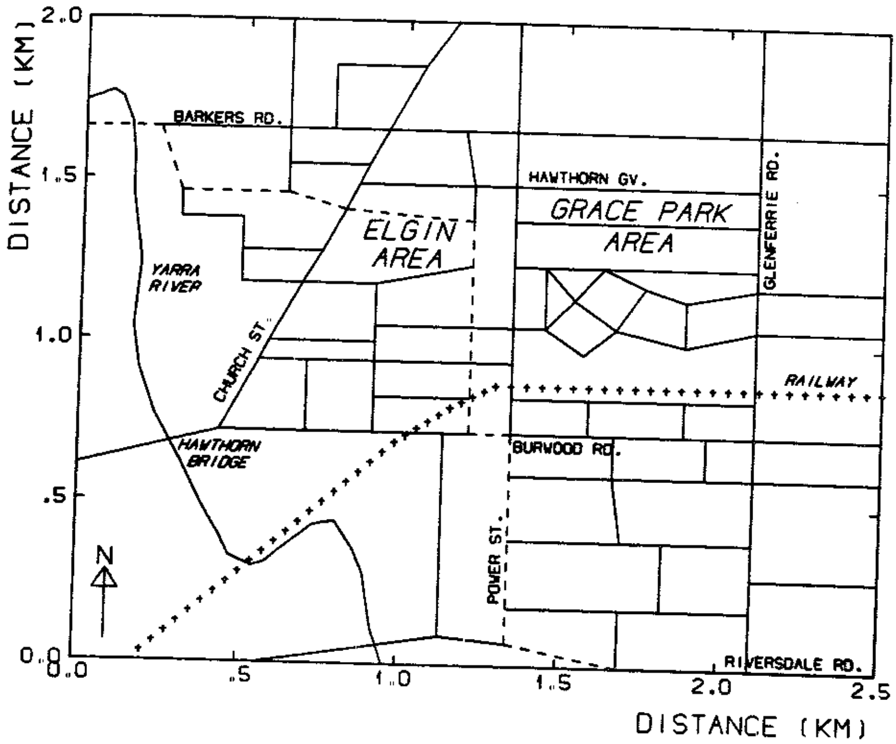

Figure 3. Path Trace using Animated Screen Display

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