COMPUTER GENERATED TRAVEL INFORMATION FOR URBAN TRANSIT NETWORKS

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ABSTRACT:

It is generally acknowledged that lack of information on available public transport services can be a constraining influence on the use of public transport. For this reason, most transit operating authorities operate some form of traveller information service. Recently, interest has been expressed in computer generated travel information systems to assist travellers in determining the best use of public transport for specific trips. This paper reviews some of the previous work in this area, and then proceeds to describe a study for the computer generation of travel information in the Melbourne transit network. The optimal path algorithm developed is described, and the input and output options are outlined. Some specific problems with respect to service reliability and the ergonomics of output media are also highlighted.

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INTRODUCTION

It is generally acknowledged that a person's use of a transport system is greatly influenced by that person's knowledge and perceptions of the characteristics of the transport system. As a consequence, the system will only be used effectively if users can obtain sufficient information about the properties of the system. Similarly, improvements to the system will only be effective if the effects of that improvement are communicated to the users and non-users. It has been shown, for example, by Brög (1982) that knowledge of the public transport system is a constraining influence in people's mode choice decisions on about 25% of occasions. The work of Ellson and Tebb (1978, 1981) also tends to confirm this effect of level of information on transit usage. It would appear, therefore, that improved methods of communication of public transport system properties may be one way of increasing the freedom of choice available to travellers, thereby increasing the use of public transport in situations where it is appropriate and offers a reasonable level of service.

Diewald, Frost and Bamberg (1983) identify six major components of a passenger information system as consisting of maps, timetables, signs, distributed information, people, and telephone information systems. Each of these components is differentially suited to providing either general information as to what services are available and how to use the system, or specific information to enable a passenger to undertake a specific trip in the system. Whilst most transit operations provide materials to convey general information as part of their overall marketing strategy, this paper will concentrate on the requirments of providing specific trip information to travellers and potential travellers, and the feasibility of using computers to generate the travel information.

The need for better information about public transport services has been paralleled, in recent years, by significant changes in computer technology which have reduced the cost and increased the capabilities of stand-alone computer facilities. The introduction of powerful and inexpensive minicomputers and microcomputers has made possible many applications which were previously not feasible. One such application is the use of computers to generate travel information for users of the public transport system. In essence, what one can now consider is the use of stand-alone computers at decentralised sites to provide information to travellers on the best way to make specific trips through the public transport system. In this way, travellers can use the public transport system in the most efficient way for specific tasks.

Although several previous studies have shown that a computer system of this type can be established, there have been several areas of further research recommended by these studies. The aim of the present paper is to review previous research on the subject and discuss potential areas for improvement. A study is reported on the feasibility of establishing a travel information system for the transit network in Melbourne. The city of Melbourne is served by a comprehensive multi-modal transit system consisting of train, tram and bus services. The study consisted of the establishment of a computerised database of route timetables; development of computer software for finding time-dependent optimal paths within the multi-modal transit network; and comparison of various methods for presenting travel information to system users. Experience gained from the study on possible improvements to existing travel information systems is then presented.

REVIEW OF PREVIOUS RESEARCH

The focus of this paper is on the generation of information about complete trips through a transit system. The paper does not address the question of providing information at transit stops about the next scheduled arrival (e.g. the Telerider systems in Canada and the U.S.), nor is it concerned with real-time information systems for transit passengers whereby information is updated by means of an automatic vehicle monitoring system (e.g. Gorstein and Tilles, 1981; Forsyth, 1985; James, 1985). Rather it is concerned with systems whereby passengers can obtain route-planning information which has been generated by computer. These systems may be used either as part of a telephone information system, or else the traveller can access the computer directly, or else the results are stored in some user-accessible format (such as microfiche).

One of the first comprehensive studies on the establishment of computerised transit travel information systems was made by the Transport and Road Research Laboratory in England (Ellson and Tebb, 1978; Pickett, 1978, 1980, 1981, 1982). The study was conducted in several stages and included:

(a) an assessment of the costs of establishment and the benefits that can be derived from the system;

(b) the development of computer software to generate travel information; and

(c) a trial system establishment at Wiltshire - a county in England with a population of approximately half a million.

The trial system was developed for an inter-urban transit network consisting of train and coach services between towns. The computer software developed was able to find, from a database of route timetables, the quickest path, or cheapest path, or path involving the least number of route changes. The output from the computer program, which consisted of travel alternatives between towns at various times during the day, was stored on microfiche and placed in travel information offices and public libraries. Although analysis showed that substantial benefits could be derived, results from the trial showed that, due to a number of reasons, both travel enquiry staff and the public were not too enthusiastic about using the system.

The main reasons given for its lack of acceptance were that the publicity campaign did not induce travellers to try out the system and staff in the libraries and information offices subsequently forgot how the system worked and how to use the microfiche readers. The list of trips included on the microfiche were predominantly multi-modal, but these types of trips were rarely required by the travelling public. In addition it could be argued that the information was not readily available at the time and place when travellers needed it most, and hence travellers perceived that it was not worth the trouble to obtain the information.

Microfiche storage of transit information was also used, but as part of a telephone information system, by the Washington Metropolitan Area Transit Authority (WMATA) in an early version of their passenger information system (Diewald et.al., 1983). They found, however, that frequent changes to routes and schedules made production of up-to-date microfiches time-consuming and expensive. The microfiches were also not suited for use in the generation of complex itineraries. As a result, the WMATA system was converted to an Automated Information Directory Service (AIDS) which utilised a computer to generate travel information (Wilson-Hill, 1982). A similar computer-aided system was also installed in Los Angeles (Wilson-Hill, 1981).

Other computerised travel information systems have been reported in the literature. The Personalised Public Transport Directory described by Williamson and Miller (1981) provides an on-line journey enquiry system in which the user indicates their zone of origin, their required destination and the time at which they wish to begin their journey. The system responds by indicating the shortest travel time route between those points at the time the user wishes to travel. The route selection allows for walking time from a hypothetical zone centroid to the network and makes allowance for buses not running to schedule by assuming that they may run up to three minutes late. Using a relatively simple test database in North Manchester they found that on-line enquiries had a response time of 1 to 4 seconds. For a metropolitan network, they estimated that the response time would more likely be in the range 10 to 40 seconds.

In discussions with operators, they found that several improvements to the system would be desirable. Firstly, it would be desirable to output a range of travel options, rather than just the absolute minimum time path, from which the user could make a selection. Secondly, the minimum time path may contain a large number of interchanges in order to achieve that minimum time. It would be desirable to have a route selection criteria which was able to minimise the number of interchanges (and other undesirable parts of the journey such as waiting time). Thirdly, it would be desirable to allow the user to specify the latest arrival time at the destination, rather than the earliest departure time from the origin.

A major difference between these studies lies in the input and output devices adopted. Whereas the TRRL study produced travel information off-line which was then accessed from microfiche, most of the recent systems engage an on-line interactive interface in which the traveller inputs travel desires and the computer outputs optimal paths. The system developed by Williamson and Miller (1981) produces travel information in a narrative printed form, while the system developed by Hayashi, Itoh and Suzuki (1983) in Japan uses input and output interfaces with graphic displays.

The Hamburg automated telephone information system (Diewald et.al., 1983) is fully automated, with no human information agents, and is capable of user - computer dialogue, with the computer speaking by means of synthetic voice generation and the user "speaking" by dialing code numbers on the telephone. An alternative method of using the system is by means of remote terminals located at strategic points within the Hamburg area. The user communicates via a keyboard and the computer prints out a personalised travel itinerary for the user.

A review of previous research has shown that few studies have been made on the practicability of establishing a widely accessible computerised travel information system for multi-modal transit trips within a large city. It is also considered that more advanced path-finding algorithms can be developed to improve the quality of travel information that can be generated.

PATH-FINDING ALGORITHMS

A Dijkstra type algorithm (Dijkstra, 1959) is commonly used in travel information systems for finding the quickest path from origin to destination. In this type of algorithm, when more than one quickest path exists, only one path is found. The choice among the alternative quickest paths is then quite arbitrary, and is normally based on the ability of a path to reach intermediate nodes as early as possible, but is not based on other more appropriate criteria such as minimising walking times, number of route changes required etc. Experience with the use of this type of algorithm for the transit network in Melbourne, however, showed that quickest paths generated are often unsatisfactory, due to the inability to select a path with the minimum number of route changes when several alternative quickest paths are present. In some cases, unnecessary route changes are made just in order to arrive at an intermediate stop sooner without causing a reduction in total trip time.

There are definite advantages in developing more advanced path-finding algorithms. Apart from the need to find the correct quickest path, travellers often wish to minimise the generalised cost of a trip rather than the elapsed trip time. For a number of reasons, however, it is often desirable, when developing such algorithms, to exclude fares from the generalised cost function. For many transit systems, fares structures are often complex and not directly related to the distance travelled. In many rail networks, for example, the fare is often dependent on the origin and destination station rather than the path used. There may also be other factors such as off peak travel concessions, season tickets, etc. which complicate the fare structure. As such fare stuctures are often revised by the transit operators, algorithms developed for a particular fare structure may soon be outdated. For the above reasons, it is considered advisable to exclude fares from the list of criteria used in determining the optimal path. If required, a separate fares-finding algorithm can be developed. This can then be used to find the fare of the optimal path, or generate a path with minimum fare.

It is proposed that a suitable path-finding algorithm is one which minimises a weighted journey time function consisting of several componments, such as in-vehicle time, walking time, waiting time and number of route changes. The system should be on-line and interactive so that the weightings to the various components of the weighted time function can be user supplied, if required.

Apart from finding paths connecting transit stations or zone centroids, there may also be a need to develop an algorithm for finding paths between any two locations as defined by their street map co-ordinates. For trips within a multi-modal transit network, there are often a number of stations within walking distance from the traveller's origin or destination. The optimal path generated should include access and egress links in a door-to-door path rather than just a path between stations or zone centroids. The algorithm can then be used to generate paths to specific named locations, such as shopping centres, the airport, or other places of interest to the general public.

Finally, the algorithm should be efficient so that information processing and generation is fast and accurate. The computer software must also be flexible and able to provide the system user with a number of options regarding the type of information required for input and output.

In connection with the Melbourne study, computer software which can find door-to-door paths with minimum weighted time has been developed. A description of details of the optimal path computer software is given elsewhere (Tong and Richardson, 1984), and some features are described briefly below.

A Time-Dependent Optimal Path Algorithm

The optimal path algorithm developed in this study provides a path with the minimum weighted time for a public transport journey between any two points in the study area. Several features of the algorithm are of particular importance to the task of providing traveller information. These features include:

(a) The transit network is described in terms of conventional nodes and links, but the movement of discrete vehicles along these links is controlled by means of the timetables for the relevant mode. In this way, fluctuations in travel time and waiting time throughout the day are automatically accounted for in the algorithm. Transfer times between modes or routes are also based on actual scheduled conditions at that point in time.

(b) The trip can be required to either begin after a specified time, or to end before a certain time (e.g. the traveller may wish to reach a destination by 9 a.m., and may want to know the latest time at which to leave the origin of the trip). The optimal path for a specified end time is calculated by using a "reversed" timetable, where all times in the timetable are replaced by a value equal to 24 hours minus the actual timetable time and then an optimal path is found from the destination to the origin.

(c) The optimal path is based on a weighted combination of in-vehicle time, waiting time, transfer time, access and egress time, and the number of transfers. Different weights can be applied to travel times on different modes. The weights to be applied to each of these times can be specified by the traveller, with a default set of weights as a standard.

(d) The algorithm can provide a number of second-best paths in addition to the optimal path.

(e) The origin and destination can be specified as any points within the study area by means of grid coordinates. For the Melbourne area, these coordinates are taken from the page and grid references from a standard Melway street directory. The optimal path program automatically connects these points into the public transport network by means of a number of access and egress links.

NETWORK DESCRIPTION

The optimal path algorithm in the travel information system requires for its operation a computerised database of route timetables, station locations and interchange walk links. For a large or complex transit network, data coding can be a time consuming task. From the experience of a trial study, it has been estimated that in order to establish a computerised network description for the urban train network in Melbourne, approximately 30 person-days of coding was required. Coding each of the other tram or bus networks would require approximately the same amount of time. It was found that route timetables were highly irregular, varying with different hours of the day and between weekdays, Saturdays and Sundays. Although computer programs were developed to facilitate data coding and checking, the data coding process is still a lengthy exercise.

The above description assumes that transit timetables are indeed available. For the urban rail network, this is not a problem since timetables are produced for distribution to the public as part of the task of preparing a set of timetables and schedules. The same applies to the tram network, although the timetables produced are not as comprehensive as rail timetables. For rail timetables, all stations are included in the timetable and hence this provides a complete database for the optimal path program. For the tram network, however, the timetables only include a selection of the available tram stops (roughly 10 to 20 percent). This therefore requires that the scheduled times of tram arrivals and intermediate stops be interpolated from the timetables at adjacent stops. This could be done by hand and the resultant data entered into the program as input data for all tram stops in the network. This, however, would result in excessive computer storage requirements for the tram network information. An alternative method which has been adopted is for the program to generate timetable information only for those intermediate stops in the immediate vicinity of the origin and destination. For the bus system the same problems exist because of the large number of urban bus routes. An additional problem, especially for the private bus systems, is the difficulty of obtaining information on the routes, and especially the timetables, operated by private bus companies. At the time of writing, only the timetable information for weekday services for rail, tram and MTA buses had been entered into the database.

From the database, a computerised network description can be generated. This network is called a basic network because it is based on stations and stops shown in route timetables. In bus or tram routes however, only major stops are shown in timetables. By coding extra information relating to the remaining stops along the routes, a detailed network description can be produced as described above. Experience from the Melbourne study has shown that in order to reduce processing time, it was advisable to use the detailed network when choosing optimal origin and destination stops but to use the basic network in other parts of the path-finding algorithm.

SERVICE RELIABILITY

A major difficulty of establishing transit information systems is how to deal with system unreliability. When services do not operate exactly according to published timetables, the travel information generated by the system may lose its usefulness and credibility. A number of approaches can be considered for overcoming this problem.

First, route schedules can be updated continuously on-line using information based on current operating conditions. Such a system is only possible either when the transit network is relatively simple, or when there is equipment available to continuously detect and monitor the locations and operation of transit vehicles within the transit network.

Second, system reliability can be taken as one of the criteria affecting route choice. Thus, a route is chosen not entirely based on minimising the weighted, average time of a trip but consideration is also given to previous records of service reliability on different routes. An estimate of trip time variability could then be included in the travel information generated. This approach however, would increase substantially the size of the database required and the processing time of the path-finding program. Even if probability concepts were incorporated into the results, however, this may not be readily understood by the general public who are expected to use the system.

Third, the system user can be supplied with additional information which may become relevant when the selected routes do not operate as scheduled. For example, at critical points along the path recommended, such as at initial boarding or interchange stations, additional information can be given on the schedules of succeeding services. This would enable the traveller to replan the journey if the recommended route was affected by unexpected cancellations or variations of transit services.

On comparison, the third approach would seem to be the most suitable solution for most urban transit networks. The main reason is that there is no requirement to code additional data, and there is no radical change to the system software used. The system is also flexible in that the traveller has the option of deciding whether the additional information is to be included in the program output or not.

It needs to be stressed that the need for route guidance does not diminish with system unreliability. The approach which should be adopted is to try to develop information systems which can take into account this factor rather than abandon the concept due to the difficulties that may arise.

INPUT/OUTPUT DEVICES AND PRESENTATION OF TRAVEL INFORMATION

Many different types of input/output devices can be used. There are also various ways in which travel desires can be input and the relevant travel information presented to the user. When the path generated is door-to-door, and the software used is one which optimises a user supplied weighted time function, the most suitable input/output device is probably an on-line interactive keyboard terminal with a video screen. The required information is obtained from the traveller through successive questions appearing on the screen. An example of the type of questions asked and the answers expected are shown as follows: (note that the exact wording and format of these questions is subject to refinement to enhance the user-friendliness of the system).

```
Enter the Melway map grid of your origin?           68E5
Do you wish to specify departure time (Y/N)?        N
Then enter latest arrival time (hr, min)?           9,00
Enter the map grid of your destination?             2HA4
The default weightings (any number from 1 to 9, a larger number denotes
less preference) applied to the following travel components are:

      in-vehicle travel = 1
      waiting at a station = 3
      walking = 5
      changing routes = 7

Do you wish to change the weightings (Y/N)?         Y

      in-vehicle travel?                            1
      waiting at a station?                         2
      walking?                                      3
      changing routes?                              7
```

The basic information which is to be presented to the traveller is a description of details of the optimal path generated, based on the travel desires which are input to the system. The description of transit routes and schedules can either be in narrative or diagrammatic form. The information can first be displayed on a video screen and a printed copy of the information can then be produced if required.

The choice between narrative and diagrammatic output will depend largely on the hardware available for output. Bartram (1980) has shown that users are better able to understand spatial information (such as a recommended transit route) if it is presented in a spatial (diagrammatic) format. For this reason, Giffen (1985) used a four-colour printer/plotter to generate maps for use by drivers using a highway route-planning system. However, the generation of maps generally requires more time and more expensive output equipment, and for this reason narrative outputs are often preferred.

Examples of path descriptions in narrative and diagrammatic form using the Melbourne rail network are shown in Figures 1, 2 and 3. The basic path description consists of station names and locations, transit routes used and schedules. Optional additional information can be included to enable the traveller to replan the journey when the original path cannot be followed due to unforeseen circumstances. For travellers who are unfamiliar with the transit system, it may be necessary to provide them with other supplementary information, such as street maps which show the locations and names of transit routes and stops.

On comparison, information in narrative form is simple and straight-forward to produce, and is also easy to understand. More information can in fact be inserted, such as the fare and the names of intermediate stations. However, this may make the information sheet more complicated. A travel information sheet in diagrammatic form has the advantage of being able to show the relative positions of transit routes and stations. This would be a useful feature for paths involving bus or tram routes where there are a lot of stops with unfamiliar names. The disadvantages are that it is more difficult to produce and the layout is more complex. Although it should be quite simple to plot a diagram showing the locations of transit routes and stations used, since all network nodes are geo-coded, the difficulty lies in finding suitable spaces in the diagram for inserting the appropriate route information text so that the two types of information do not overlap.

An alternative to the production of written output for the use of the traveller is for the computerised travel information system to be used to augment the information currently provided by telephone-based traveller information services. The computer program could be used by the operator, based on information supplied over the telephone by the traveller, and then the travel information generated by the program could be relayed verbally to the traveller over the telephone. Using the computer system in this way obviates the need for precise ergonomic design of the input/output interfaces, since the operators would all be relatively skilled in the use of the system.

Basic information	Map code		Station name	Additional information
Origin at	68E5	*		
3 minute walk		:		
Depart 8:26 am	68E5	*	Glenhuntly	Next departure
		:		8.37 am
		:		
		:		
		:		
Frankston Line		:		
		:		
		:		
Arrive 8.44 am	2FG5	*	Flinders	Arrive 8:56 am
		:	Street	
3 minute walk		:		
Depart 8:47 am	2FG5	*	Princes	Next departure
		:	Bridge	9:02 am
		:		
		:		
Epping Line		:		
		:		
		:		
Arrive 8:51 am	2GH4	*	West	Arrive 9:06 am
		:	Richmond	
5 minute walk		:		
Destination at	2HA4	*		

Figure 1: Travel information in narrative form.

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Leave your origin (Melway map code 68/E5) at 8.23 am and walk for 3 minutes to Glenhuntly Station (Melway map code 68/E5).

Catch the 8.26 am train on the Frankston line travelling towards Flinders Street.

(If you miss this train, the next one is at 8.37 am).

Alight at Flinders Street (Melway map code 2F/G5) arriving at 8.44 am.

The 8.37 am train will arrive at 8.56 am).

Walk to Princess Bridge Station (Melway map code 2F/G5) arriving at 8.47 am.

Catch the 8.47 am train on the Epping line travelling towards West Richmond.

(If you miss this train, the next one is at 9.02 am).

Alight at West Richmond (Melway map code 2G/H4) arriving at 8.52 am).

(The 9.02 am train will arrive at 9.06 am).

Walk to your destination (Melway map code 2H/A4) arriving at 8.56 am.

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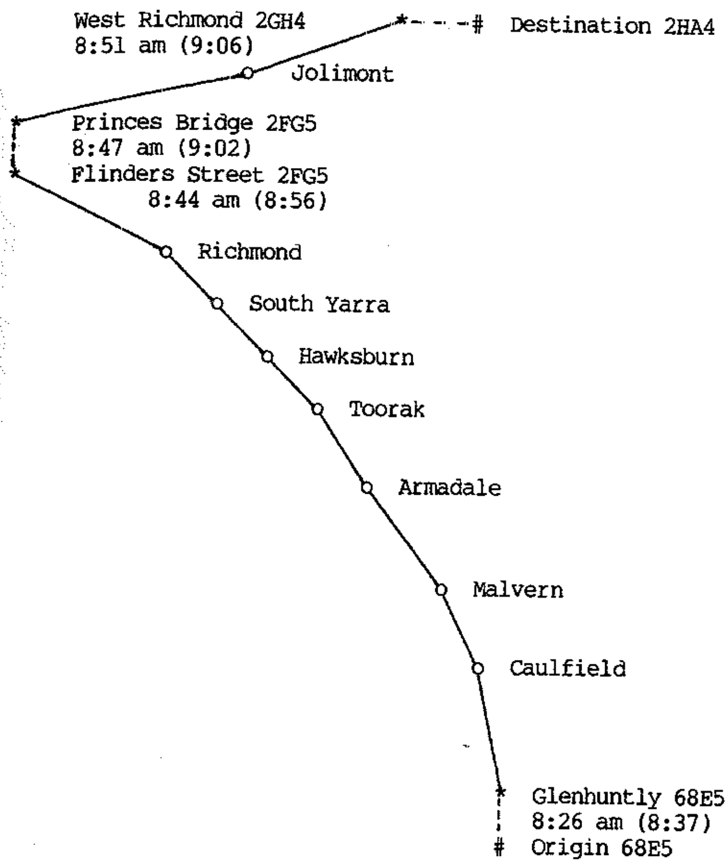
Figure 2: Travel information in alternative narrative form.



Note: Times shown indicate scheduled vehicle departure or arrival times. Time shown inside brackets indicate next scheduled departure or arrival time.

Legend:
- # origin or destination specified
- * start, end or interchange station
- o other station type along the path
- —— train
- ---- walk

Figure 3: Travel information in diagrammatic form.

COMPUTER REQUIREMENTS

In the Melbourne study, the system was developed on a VAX 11/780 computer. The system software was written in Fortran and hence can be converted for use on different types of computers, including mini- and micro-computers. The main constraint lies in the capacity requirements of the system. In the Melbourne transit network, the database of weekday timetables for all train, tram and MTA bus services requires a storage capacity of 400 k bytes. However, for a particular optimal path computation, it is only necessary to use a portion of the database, i.e. timetables for a selected 2 hour period with the day. Hence, the required capacity of the programs will generally be below 150 K bytes. The processing time required to generate an optimal path would of course depend on a number of factors, such as the length and complexity of the paths considered, and the type of path information detail required. For a network with approximately 500 nodes and 3000 arcs, the CPU time required for generating an optimal path with a user specified weighted time function will normally be less than one minute.

COSTS AND BENEFITS

Having outlined the development of the basic components of a computerised transit information system, it is useful to recapitulate on the major costs and benefits associated with such a system, so that system implementation can be considered in the light of these factors.

The main costs of establishing a transit travel information system are:

(a) staffing costs required for the setting up of a database of transit timetables;

(b) costs for development of computer software; and

(c) computer hardware costs.

The benefits that can be derived from the system by the transit operator are:

(a) attract more transit users through improved information services;

(b) supplement information provided by existing information services, such as telephone-based answering of queries concerning transit services, and the printing of route timetables; and

(c) when supplemented with other program software, the system can be used for the planning and evaluation of route schedules.

The benefits that can be derived from the system by transit users are:

(a) more detailed and up-to-date information on transit services; and

(b) accurate guidance on optimal use of transit services with user supplied travel preferences.

CONCLUSION

A review of previous research and results from the Melbourne study showed that there are several areas in which computerised transit travel information systems can be improved.

First, there was a need for improved minimum path algorithms. For complex multi-modal transit networks in particular, conventional quickest path algorithms may not always generate a satisfactory path. There was a need to develop algorithms which can generate optimal paths by minimising weighted trip time, where the weightings applied to each component in the weighted time function are user specified. Such an algorithm has been described by Tong and Richardson (1984).

Second, path-finding software needs to be more flexible and provide the user with a number of options concerning the information to be input and output. For example, the algorithm should be able to generate paths connecting two points as specified by street map coordiates which are not necessarily transit stations and travellers should be able to specify the arrival time of a trip rather than the departure time.

Finally, various types of input/output devices and various ways of presenting travel information can be employed. More research should be directed to this area, especially to thè graphic display of route information.

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