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Analysis of Signage Requirements for Pedestrian Movements

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Abstract

Role of passive guidance facilities such as conventional street signs in the context of way finding is analysed. In particular, effects of lack of signage are investigated using a simulation model. The analysis has focused on grid networks for the preliminary studies reported here.

The objective of the project is to contribute to the analytical basis related to signage planning. Proper signage costs substantial amounts to erect and maintain while lack of signs cause frustration to users, wastage of energy and travel time and imparts a poor image of the professionalism of planners Planners involved in pedestrian movements within city centres, shopping plazas, large institutions, transport interchanges and exposition sites can benefit from this investigation. Lessons learned here have implications on street signage in general and are not limited to pedestrian traffic management. NAASRA guides and other relevant publications are reviewed to establish current standards and practices as a prelude to the model formulation

The simulation model is based on the assumption that the primary objective of pedestrians is the minimisation of destination search time An interesting outcome of results presented in the paper is the ability of this model framework to be applied to find the optimum user response for lack of signage. This aspect may be useful for developers of community education campaigns where thorough signage costs are prohibitive. Different systematic destination search strategies in a partially designated network are investigated and the quantitative analysis has identified an intuitively meaningful strategy for pedestrians who have to negotiate networks with poor signage

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Introduction

In recent years there is a significant interest about active guidance systems that rely on various communication strategies. Nevertheless the general community still relies on passive guidance facilities to a large extent and scope for improvement strategies need to be further investigated. The focus of this research project is to investigate the optimality of number of guidance signs provided from the point of view of cost of signage and ease of locating the destination.

The destination search processes within city centres, airports, exposition sites and within numerous large institutions in general rely on signs to assist the pedestrians. The ability to locate the destination without extensive random search is important to travellers as well as service providers

Ramsay and Luk (1997) have already identified features that should be taken into account in the design and planning of on-road information signs and displays. These features include the type, information content, the size and conspicuity, the frequency of updating and location of the sign. However, these guidelines do not specify the frequency of signs. This study attempts to investigate the number and optimal location of the static information facilities that need to be installed to serve road users including pedestrians.

Our treatment of the problems is mainly simulation oriented. The accessibility is determined by simulating a set of alternatives to select the best alternative. Network analysis methods are adopted to facilitate quantitative treatment of signage location problems on networks. The finiteness of the link and node sets enables us to obtain efficient procedures to determine optimal locations on networks. The intention here is to establish the theoretical basis required to develop signage frequency policies

Information demand

Accessibility information is an essential element of facilities used by public. For a public facility to be effectively used, the public must know where, when and how often the service is provided. Traditionally, network maps have been used in an attempt to provide the necessary information to the general public. These are, however, being superseded by new media available to communicate information to public.

Much of the information required by users is already available from various urban traffic control centres. Information on congestion, weather condition, traffic incidents and changes in the road network brought about by re-construction and maintenance is sought by police and motoring organizations and efforts are made to use this to the best advantage. The main challenge lies in the field of information transfer covering issues such as where, when, quantity, content, technology and cost of information. These issues have relationships among each other forming a triangular set of relationships as shown in figure 1.

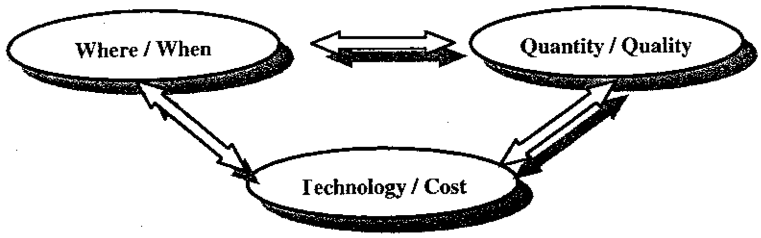

Figure 1 Elements of Information Providing

From the road user or pedestrian point of view, it is important to ensure that the information is available at anywhere and anytime along the network, and the message is easy to understand.

Road signs are provided to control and regulate road users, to warn them of potential permanent or temporary hazards, and to provide information and guidance to assist in their travel There are three types of traffic signs, named regulatory, warning and guide signs (Quebec Road Department, 1968; Donald, 1995; Underwood, 1995). It is the guide signs that we are interested in this project.

Destination search theory

Random walk theory provides a basis for modeling destination search process when there is no guidance. Consider a person travelling on a grid network without information using a random search strategy. In its simplest form, this problem is known to mathematicians as Drunkard's walk Here a drunk walks home from the bar. Leaving the bar, he or she happens to randomly choose the direction (turn left or right) to proceed. Then at each of the intersections a random direction is chosen again And this random direction selection is the key to his or her destination search process. Provided the network is limited and small, he or she will eventually find the destination.

In real life, there is a possibility that the person searching a destination inadvertently finds a similar facility or a competing-service provider. For example, consider a person looking for a particular fast-food outlet, but during the random search process happens to find a competing fast-food company. This is a less than satisfactory outcome to the original vendor In the theoretical framework, this is akin to the drunkard landing on the footsteps of the police station, before reaching home. Figure 2 illustrates a random walk process in a two-dimensional grid network. The first thirteen states of a simple random walk in Z^2 are illustrated.

Simulation model

A computer program is developed to simulate the search process and count the number of nodes visited. The software is able to handle the destination search process in two-dimensional grid networks, where the nodes at which sign boards are available can be individually identified

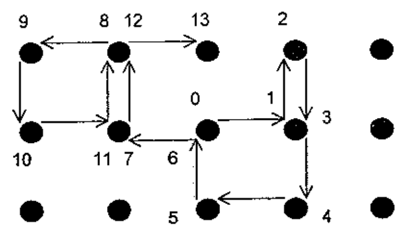

Figure 2. A sample random walk in two dimensional space

The flowchart of the computer program is shown in figure 3 The algorithms of the simulation program developed in this study first establish network characteristics along with the origin and destination nodes. The number of simulations can be specified to mimic the movement of a given number of road users. It is required to define the turning movement probabilities at intersections. Using a random number generator, a turning movement direction is selected and the trip continues until the destination is found. Limitations are imposed to ensure the road user does not leave the network.

The computer program provides the number of nodes (intersections) visited during a given simulation This is applied to compute the average numbers of nodes visited by road users under the particular information display strategy. A statistical analysis of accessibility is performed later using a spreadsheet software.

The statistical analysis of accessibility is performed to investigate the effect of variation of network size, turning movement probabilities at intersections and information level on search distance, cost and user optimum strategy of path selection.

Network characteristics

There are two types of networks we can consider. These are open and closed graph networks (Doyle et al, 1984). Figure 4 is a schematic explanation of the closed and open graphs. A characteristic of a closed graph pattern is the bound barrier such that the complement set of the barriers (boundary) is connected The traveller does not require to make U-turns at the boundary, because along the connected boundary there are alternative paths available to proceed On the other hand, in the open graph network patterns the traveller may need to make a U-turn at the edge of the network to return to the body of the network

In the analysis provided here, only closed graphs are considered. In other words, it is assumed that the zone boundary is well demarcated and the traveller has no opportunity to cross that boundary. In reality though, this assumption is not always valid in street situations. It is a perfectly valid assumption though within transport interchanges, expositions and large institutions where the boundaries are clearly identifiable

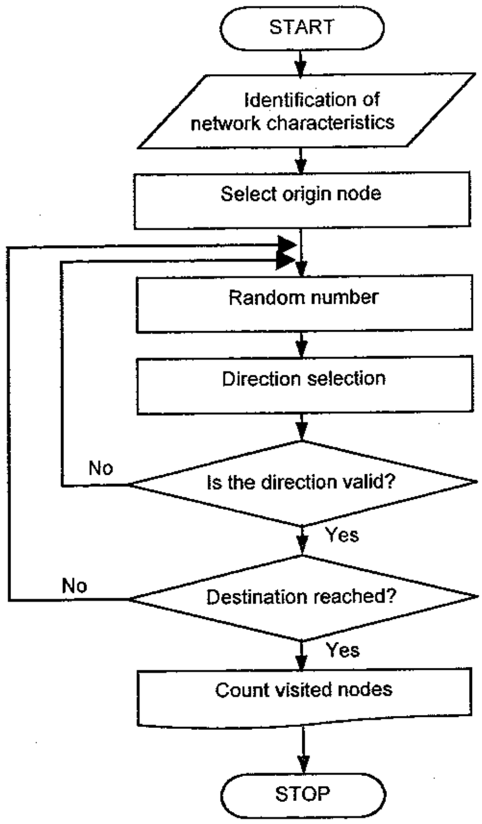

Figure 3 Flowchart of the simulation program

This study is intentionally kept limited to rectangular network patterns with uniform link and intersection characteristics. The closed graph pattern that is considered is illustrated in Figure 5. The analysis is based on applications on several sizes of networks (by varying the numbers of nodes). There are eight sizes of the rectangular network analysed during this project. The smallest network has a 3-node side and therefore 9 nodes in all in the network (see Figure 5 left). The largest has a 10-node side (see Figure 5 right). This network has a total of 100 nodes.

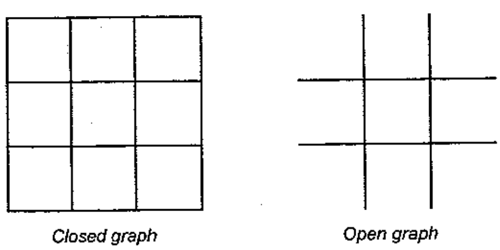

Figure 4 Closed and open graph

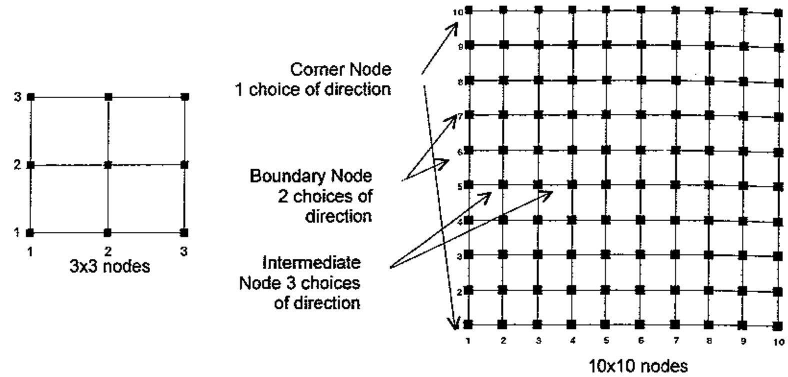

Figure 5. The network pattern

Modelling of the destination search process

The random walk approach allows the assessment of travel distances assuming that the pedestrian begins his/her journey from the origin node and travel to the destination without any idea or guidance as to where the destination is. The traveller is assumed however able to recognise the destination site when he or she is at that node. In other word, it is assumed that the trip ends at the first encounter of the destination node. These travellers make a random selection of the travel direction at each intersection node.

At the origin node (X_o,Y_o), the traveller randomly chooses a direction from four choices (North, East, South or West). At the next node, there would be a maximum of only 3 directions to consider as no U-turns are allowed in the present analysis. At certain nodes, there maybe only two or one available direction to proceed. These are the nodes at edges and corners of the network. Traveller that reaches the edge selects his/her direction randomly in one of the two available paths. As no U-turns are allowed, there is only one exit path available at a corner of the network.

Turning movement probability

It is likely that a certain traveller prefers to pick a particular direction when there is no guidance information. This feature is specifically built into the software developed for the purpose of analysis. The probability of direction selection at an intersection is a user selectable variable in this software. The simulation experiments have been carried out for a range of values of this variable. As a first trial during this project, the straight through movement has been allocated a high probability to mimic the general pedestrian behaviour. Here, the pedestrian has a probability of 0.6 to go straight, 0.2 to turn left and 0.2 to turn right. In a later experiment, this variable has been allocated a range of values. The turning movement probabilities at an intersection for the initial trial are illustrated in Figure 6.

In the analysis of road user optimum strategy, the efficiency of path search is analysed by systematically covering several combinations of probability distributions for turning movement. The average number of nodes visited is selected as the main criterion in determination of the optimum strategy. The average number of nodes visited is directly proportional to the distance travelled in the search of the destination.

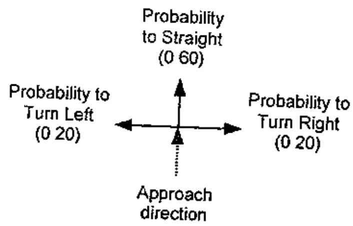

Figure 6 Turning movement probabilities

Effect of network size under no signage

This section documents the analysis of accessibility for variety of sizes of networks. There are eight sizes of the rectangular network that is investigated (from 3 node to 10 node sides). Each network size is tested for 1000 simulations. The frequency and the average number of nodes visited are calculated from the simulation.

Figure 7 shows the frequency of number of nodes visited by road user or pedestrian in the 3 node sided network. Probabilities of turning movements are 0.2, 0.2 and 0.6 respectively, for left turn, right turn and straight through movement. This experiment assumes guidance signs are not available in the network. The shortest path contains 4 nodes and the longest path contains 42 nodes. The average number of nodes visited is 6.35 nodes. It is interesting to note from Figure 7 that about 67% of the simulated population found the shortest path in this small network during their random search. This network is perhaps similar to ones found in small regional towns. Only about 10% of the simulated population visited up to 7 nodes before finding the destination and therefore performed a wasted travel of 3 links. About 2% visited up to 10 nodes.

The analysis is continued to investigate the average number of nodes visited for eight variations of the network size (edge sizes from 3 to 10 nodes as mentioned before). The simulation has been repeated for 30, 50, 100, 300, 500 and 1000 times to investigate the statistical adequacy of the number of simulated persons.

The number of nodes visited is computed as a proxy for the average distance covered by the road user or pedestrian. Figure 8 presents the average number of nodes visited for the range of network sizes with turning movement probabilities 0.2, 0.2 and 0.6 for straight, left and right movements respectively. It is shown that the average number of nodes visited in a particular network size has stabilised after 300 simulations. In this research project, hereafter 1000 simulations are performed in estimation of average measures to ensure statistical accuracy.

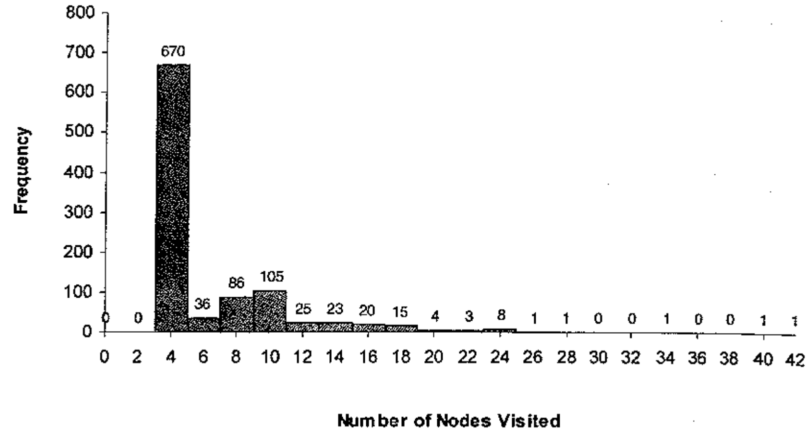

Figure 7. Frequency and average count of nodes visited (for 1000 simulations) for 3-node sided and no signage network

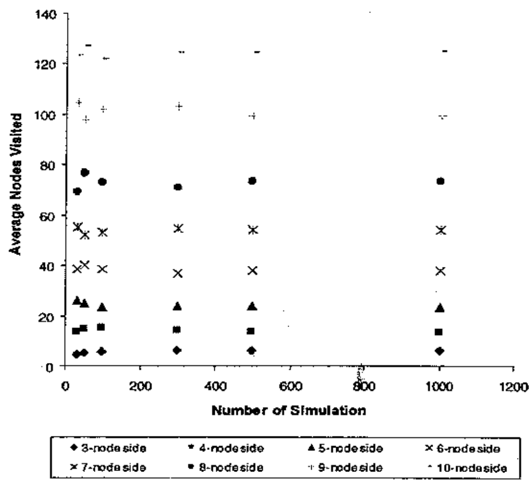

Figure 8. Average number of nodes visited for various sizes of networks with turning movement probabilities 0 2, 0 2 and 0.6 for left turn, right turn and straight through movements respectively

Quantity of signage

Investigation here is based on four signage location options They are;

(a) No signage, there is no guidance signs in the network.

(b) Corner signage, there are just 2 signs in the network that are located at the corners of network.

(c) Edge signage, where the signs are located along boundary of the network at the side of destination node.
(d) Maximal signage, where all intersections have a guidance sign.

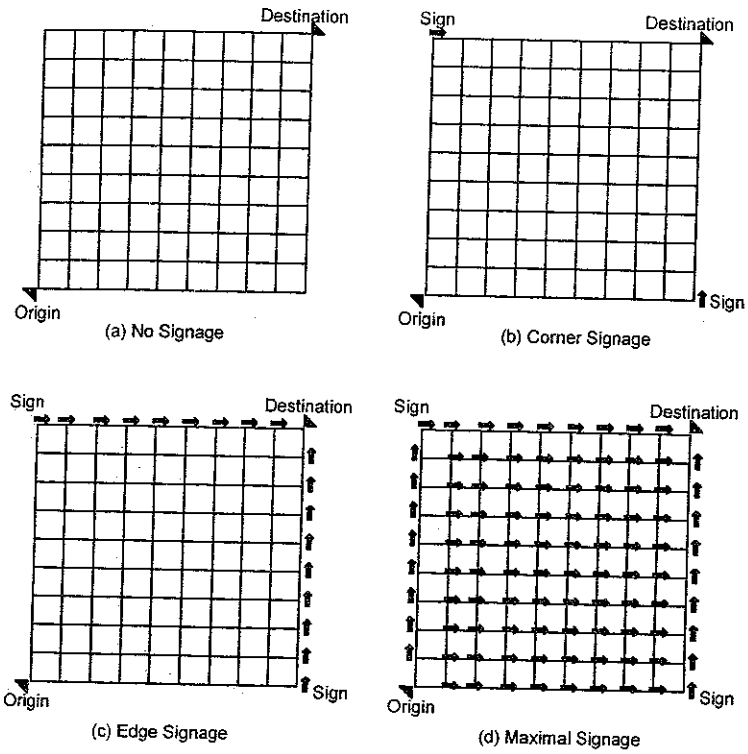

Figure 9. Signage options considered

Figure 9 illustrates the location of signage for the four options mentioned above. This illustration is for a 10-node sided network. The number of signage sites for each option is mentioned on table 1. For visibility reasons, it is possible that some sites require multiple signs. What is mentioned in the table is the number of signage sites. The tabulation shows the number of signage sites required in order providing information to road users; just for one particular destination node. In practice though there are numerous significant destinations the road authority or system operator may have to support with adequate guidance information.

Table 1 Number of Signage on Variation of Network Size

Signage Option	Edge Size (Number of nodes along a side)							
	3	4	5	6	7	8	9	10
No Signage	0	0	0	0	0	0	0	0
Corner Signage	2	2	2	2	2	2	2	2
Edge Signage	4	6	8	10	12	14	16	18
Maximal Signage	7	14	23	34	47	62	79	98

Figure 10 shows comparison of accessibility with different levels of signage (no signage, corner signage, edge signage and maximal signage) provided for pedestrians in the network. It shows that with the increment of network size (number of nodes), the pedestrian accessibility with no direction signage is deteriorating. The wasted number of nodes visited by such pedestrians during random search process in large networks is of high magnitude. For example, in a 100-node network, the pedestrian with no information has to visit an average of about 100 nodes extra before finding the destination. Figure 10 also shows the R^2 value for the non-linear regression curves. As R^2 values are close to 1, the edge size explains a large part of variation in the average number of nodes visited.

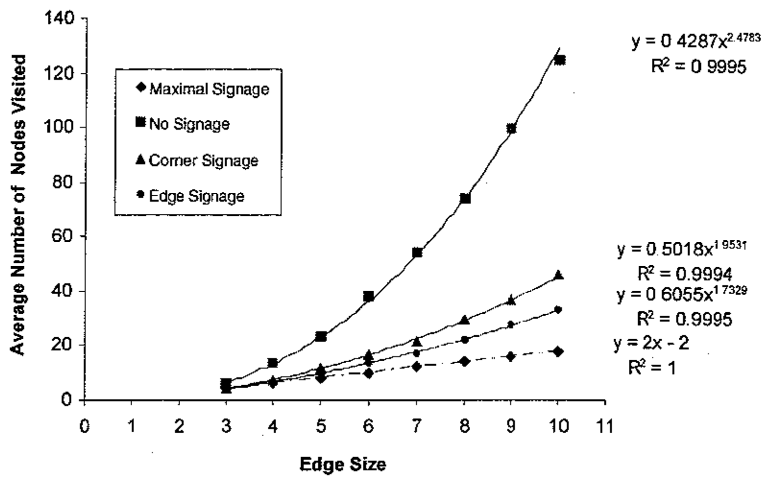

Figure 10 Average number of nodes visited under different signage strategies

The average number of nodes visited by pedestrians with variations of the signage policy in terms of the total number of nodes in networks, is presented in Figure 11. This figure shows a linear behaviour, which is more convenient for analytical work. It shows that the average number of nodes visited is decreasing with additional number of signage in given size of network. For example, at 100 node network size, the average number of nodes visited is 124.7 nodes for no-signage, 45.88 nodes for corner signage (2 signs), 33.23 nodes for edge signage (18 signs) and 18 nodes for maximal signage (98 signage sites).

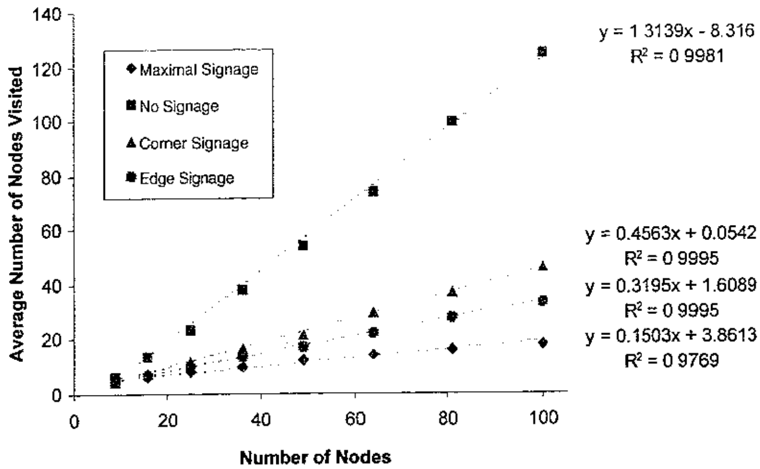

Figure 11 Relationship between average number of nodes visited and the number of total nodes of network.

The comparison of average number of nodes visited for each signage option and the shortest path is presented in Figure 12. Figures 11 and 12 also record the R^2 values for calibration purposes. The R^2 values for all options are near unity and support the linear relationship.

Figure 12 indicates the amount of wasted travel performed due to lack of guidance information. For large networks, even the simplest information level (i.e. 2 corner signs) removes almost 2/3 of the wasted travel during random search process.

Cost analysis

The objective of the cost analysis is to minimize the sum of the transportation cost and the setup cost. For the purpose of illustration, it is assumed that the cost to provide signage is $10.00 per sign per day. The number of travellers is assumed to be 1000 per day. Equally spaced nodes, travel cost of 50 cents per km and link length of 200 m are also assumed. Figure 13 presents the total cost under various sizes of networks with different signage options.

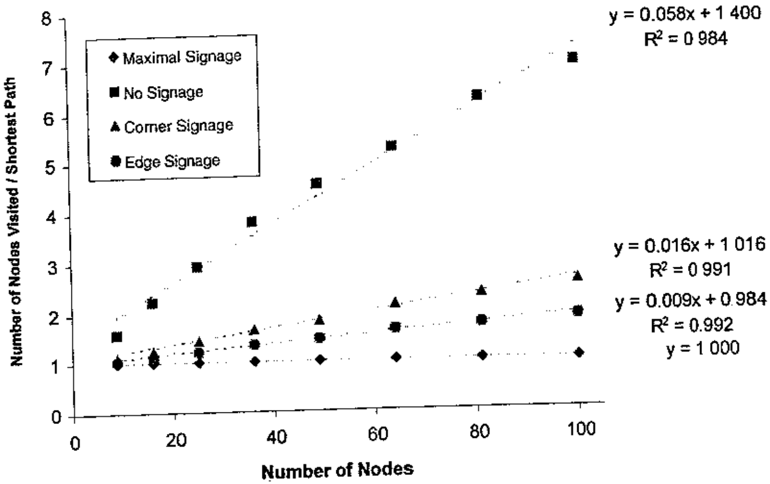

Figure 12. Comparison of average number of nodes visited and shortest path

Figure 13 shows that the maximum total cost is with the no-signage option, because the wasted number of nodes visited by pedestrians is large in that particular network The minimum total cost for networks with up to 20 nodes is the corner signage option, but for more than 20 nodes the best is the maximal signage option. For networks with more than 20 nodes, the average number of nodes visited with no information is large and any level of signage is shown to be useful.

Now let us look at variations of set up cost. The analysis reported here is based on 100 node networks As the ratio of signage cost to transportation cost (where transportation cost is the travel cost times travelling population) is increased, the total cost of maximal signage option increases. Here, a range of setup costs of signage per day; $10.0, $20.0, $30.0, to $100.00 are selected and other parameters are maintained same as with the analysis before. The result of this analysis is shown in Figure 14.

The minimum total cost for ratio of signage cost to transportation cost up to 0.2 is the maximal signage option. Between 0.2 to 0.8 of this ratio, the best option is the edge signage. Beyond 0.8, corner signage is found to be the best option

The lesson from Figure 14 is that the minimum total cost is influenced by the ratio of signage cost and transportation cost The minimum cost for small ratio of signage cost to transportation cost in a 100 node network is the maximal signage option with edge signage being closely suitable It is also seen that the no-signage option is a costly policy.

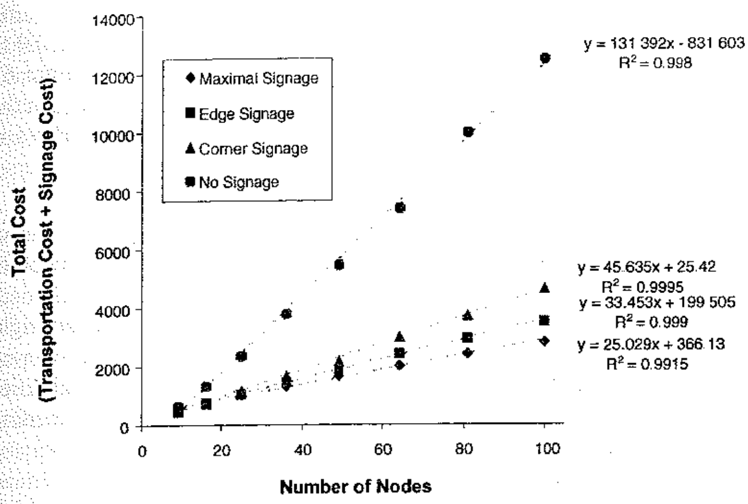

Figure 13. Sum of travel and signage cost of different size networks

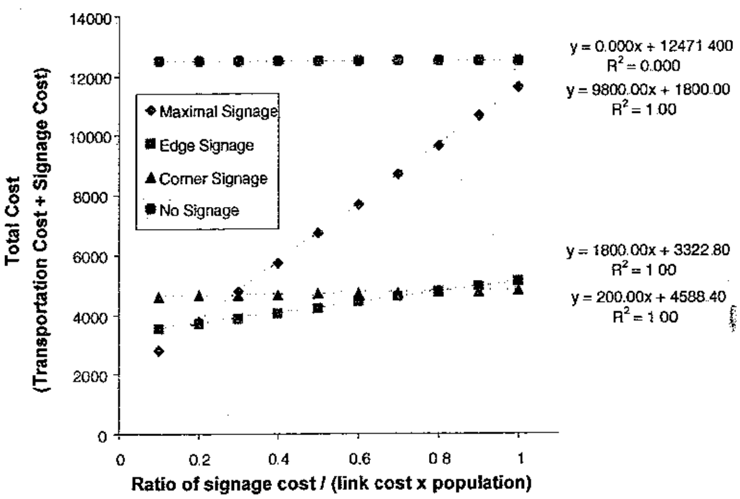

Figure 14. Total cost under various signage cost options in 100 node network

User optimum turning direction

The pedestrian accessibility under a particular set of movement probability distribution has already been discussed. Now, an attempt is made to investigate the optimal probability of turning movement at an intersection. To obtain the user optimum turning movement strategy a series of probabilities of turning movements at intersections has been investigated. The analysis is based on the average number of nodes visited by travellers in a no signage network consisting of 100 nodes. The probability of turning movement at an intersection is varied from (0 9 to go straight, 0 1 to turn left and 0.0 to turn right) to (0.0 to go straight, 0.1 to turn left and 0.9 to turn right). There are 63 variations considered to find the user optimum turning direction selection strategy in the absence of guidance information. As before, the average number of visited nodes is obtained from 1000 simulation experiments.

Figure 15 presents results of this analysis in the form of a contour diagram It shows that the average number of visited nodes in the 100 node network under different probability distributions of turning movement For example, the traveller that chooses the turning movement probability 0.8 to go straight, 0.1 to turn left and 0.1 to turn right is travelling for about 60 nodes searching for the destination node in a network with no signage. The corresponding value is 121 nodes with the turning movement probabilities 0.6 to go straight, 0 2 to turn left and 0 2 to turn right, and 383 nodes for the turning movement probabilities 0.2 to go straight, 0.4 to turn left and 0.4 to turn right

It can be seen from the figure that the average number of nodes visited is decreasing with increasing probability of proceeding straight through in the no-signage network What this means is that, the destination search of motorists and pedestrians improves when the probability of proceeding straight through is high provided the network is closed at the boundary.

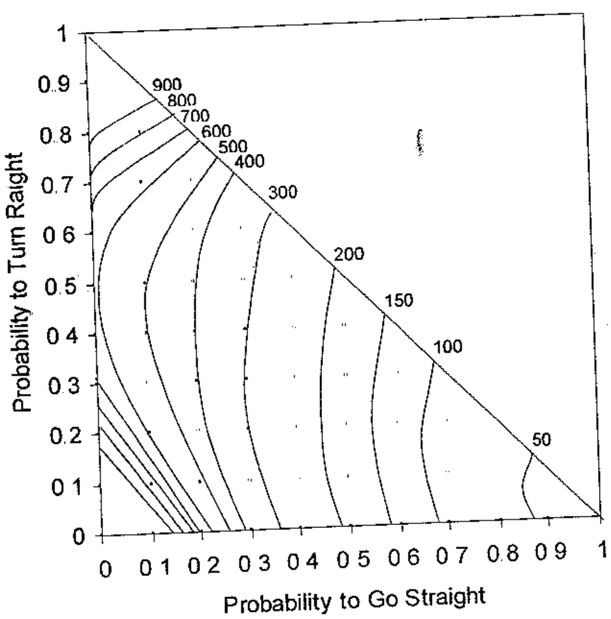

Figure 15. Average number of nodes visited in a 100 node network under different turning movement probabilities

The contour diagram shown in the figure represents equal number of nodes visited for various turning movement probabilities. The user optimum is achieved by keeping this number low. The message from this figure is that, with no information, the best strategy is to go straight through at the intersection in a closed network. It may be useful to extend the analysis to include different network patterns, (such as a circular, triangular, hexagonal and the other patterns), and a mix of network patterns.

Recommendations

This study has reviewed the concept of direction information delivery policy required to improve the accessibility of the pedestrians. The methodology adopted here is based on simulation processes. This study is intentionally kept limited to rectangular networks with uniform link and intersection characteristics. The analysis is based on the assumption that the primary objective of pedestrians is the minimisation of destination search time. An interesting outcome of results presented in the paper is the ability of this model framework to find the optimum user response for lack of signage. This aspect may be useful for developers of community education campaigns where thorough signage costs are prohibitive. Destination search strategies in partially designated networks are also investigated and the quantitative analysis has identified an intuitively meaningful strategy for pedestrians who have to negotiate networks with poor signage.

It is shown that the pedestrian accessibility is deteriorating with the increment of network size (number of intersections), with no direction signage. The wasted number of nodes visited by such pedestrians in large networks is of a high magnitude.

It is also shown that the accessibility is influenced by the turning movement probabilities adopted by pedestrians. The analysis has shown that the average number of nodes visited by travellers with propensity to go straight through is low in this closed network. The average number of nodes visited decreases with additional sites of signage in a given size of network.

The amount of wasted travel performed due to lack of guidance information has been computed. For a large network, even the simplest information level (i.e. 2 corner signs) removes almost 2/3 of the wasted travel. It is also shown that the minimum total cost is influenced by the ratio of signage cost to transportation cost. The minimum cost for a small value of this ratio in 100 node network is given by maximal signage option with edge signage being reasonably suitable. The no-signage option is an expensive policy to the community when transportation costs are included in the cost analysis.

The results of the current project have been encouraging and provide an insight into signage location selection policies. The outcome of this project is useful knowledge for service providers. Also, from the point of view of individual travellers, the model has revealed the level of effectiveness of path selection strategies in the absence of directional signs. Applications of this model are not limited to path searching within transport interchanges, retail shopping complexes, office buildings, hospitals and large recreation complexes. The model can well be applied in the context of road network in urban centres, rural centres and neighbourhoods The importance of guidance signs is well understood by certain retail shopping complexes and fast-food servers who already invest well on signage to assist travellers.

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