Performance of DRGS in Different Size Networks.

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Abstract:

The Dynamic Route Guidance System (DRGS) concept is one method available to improve the efficiency of the road traffic network. The need for developing DRGS evaluation model has been dentified and the structure of the framework has been reported earlier. The evaluation model adopts simulation techniques using an event update microscopic simulation method. The model accounts or guided and unguided motorists as two distinct types of road users and their route selection rocess has been modelled to reflect the behaviour with or without dynamic route guidance nformation. Unguided motorists have been further classified as passive and active motorists to allow or modification behaviour of some unguided motorists.

n the research presented here, an attempt has been made to investigate the application of DRGS oncept on different size networks. The model has been applied to study three networks referred to s small, medium and large network. Each network has been investigated under varying proportions f guided motorists. The preliminary investigations suggest that DRGS concept could be more ffective in relatively large networks. The findings also suggest that DRGS can be an effective easure to reduce the network-wide congestion.

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1. INTRODUCTION

Analysis of the contribution from technological innovations to broader transform reform issues requires specific analytical tools that allow assessment of transport performance under normal operating conditions. For example, increased attention is currently being given to the feasibility of Route Guidance Systems (RGS). Although the technological feasibility aspects are of substantial research interest, it is also important to develop tools that allow researchers to plan ahead for the operating environment the proposed technology will bring forth.

Unlike conventional systems which control traffic in time and space in an independent fashion, Dynamic Route Guidance Systems (DRGS) offer potential to manage traffic with specific attention given to dependencies in the time and space dimensions. Typically, DRGS operate by directing individual vehicles over less congested routes and hence distributing the traffic more evenly over the network. In the simplest form this may be achieved by variable signs on the road side; in more refined forms this will be achieved by instructions provided to on board navigation facilities.

Research has already shown that potential benefits in terms of travel cost savings can be significant and the DRGS concept merits serious consideration (Armstrong, 1977). Jeffery (1981) has already attempted to quantify possible waste of transport resources due to traditional route finding methods. For example, it was estimated the excess travel in Britain in the year 1979 was about 6 billion veh km by drivers who sought, but failed to identify, shortest routes on unfamiliar trips greater than 5 km in length. This excess travel was worth about 5.4 billion Pounds Sterling. Similar estimates with 1983 data in the US reported by King and Mast (1987) indicate that excess travel accounted for 45 billion US Dollars. The corresponding excess travel statistics are not yet available for Australia, although it is quite evident that in several state capitals in Australia there is a considerable amount of excess travel because route choice methods and traffic management methods are similar to overseas standards. Main causes of excess travel in urban road networks are the limited size of the route choice set considered by the drivers and their inaccurate perceptions of traffic conditions. Various forms of route guidance methods are being considered by researchers to improve the road network performance by eliminating inefficiencies because of the poor level of information available to individual drivers.

DRGS is an attempt to automate the acquisition, processing and transmission of performance data. To assist motorists in selection of their optimum routes, various RGS are being developed. These systems can be broadly classified as non-vehicle and in-vehicle route guidance systems. Non-vehicle systems are further classified as manual and electronic RGS. In-vehicle systems are sub-classified as static and dynamic RGS. Table 1 lists a few commercially available RGS under each category. Typically, a DRGS consists of a central computer, supported with historical as well as real time traffic information over the network, and vehicles able to receive transmissions from central computer. Drivers of such vehicles are known as guided motorists in this paper. All guided motorists are in a certain degree of contact with the main computer via a communication network. The objective of the system is to identify optimum routes for guided motorists and to navigate them through their journey. Unguided motorists are not equipped to receive such navigational assistance. They make their route choices based on their familiarity with the network and traffic conditions.

Table 1 Commercially available route guidance systems

System capability	Non-Vehicle Manual	Non-Vehicle Electronic	In-Vehicle Static	In-Vehicle Dynamic
Route reference	Maps Signs	ATLAS STREETS	NAVIGATOR DRIVEGUIDE	DIALOG CLASS
Route planning	Maps SRI	STREETS AUTOROUTE SRI ROUTE-TEL		
Route guiding		CDD PATHFINDER	CDD Q-ROUTE MICROPILOT CARIN ALI	EURO-SCOUT CARMINAT AUTOGUIDE FAST-TRAC

Source: Based on Bovy and Stern (1990)

The model presented in this paper has already been applied for investigation of other aspects of DRGS such as estimation of travel time savings under different proportions of guided motorist population (Upadhyay et al., 1994a), and the effects on unguided motorist population. The results of the earlier research concluded that DRGS is more effective in relatively higher travel demand and provides benefits to both guided and unguided user communities. In this paper, the DRGS model has been applied to investigate the effects of the size of the networks under different travel demands for each network.

2. DRGS EVALUATION MODELS

DRGS projects require substantial investments because such systems rely on expensive telecommunication and high speed computer hardware. Thus, it is important to assess the cost effectiveness for any DRGS project prior to implementation. Many transport professionals involved in the development and implementation of DRGS are often challenged by the question of cost effectiveness of such systems. The analysis of cost effectiveness primarily requires an assessment of system performance measures such as savings in travel cost, reduction in traffic congestion, improvement in travel safety and environmental impacts. Also, the cost of project may significantly vary from one network to another, depending on their configuration, size and prevailing traffic conditions.

Literature review

There have been a number of studies in the past aimed at developing evaluation models which are suitable for DRGS projects. Tsuji et al. (1985) presented an evaluation model based on an analytical formulation. They applied stochastic concepts to measure the effectiveness of the road transport system. The effectiveness of the RGS was measured in terms of probability of the guided (intelligent) motorists arriving at their destinations earlier than the unguided (normal) motorists. One of the important findings was that the effectiveness of route guidance system increased in unpredictable traffic conditions such as irregular traffic jams, public events and incidents.

Hounsell et al. (1994) have reported another DRGS evaluation model based on CONTRAM, which is a dynamic equilibrium traffic assignment model. They have concluded that DRGS benefits are higher at lower levels of DRGS subscription. Also, the benefits to the DRGS subscribers are substantially high in the event of traffic incidents.

Simulation techniques have been adopted in some of the recent evaluation models. Chen and Mahmassani (1991) studied the route choice modelling process in a congested network. Four information processing strategies such as no information, home based pre-trip information, en-route information and both pre-trip and en-route information strategies are included in this model. Using the simulation assignment model, they estimated the travel times for different categories of users and supported the effectiveness of DRGS concept. The model has been applied on data representing three parallel corridors of a grid network. The objective of their research work differs from that of the present, as their project was directed at studying the reliability of the route guidance information system rather than the economic evaluation.

Another research team also adopted the simulation approach for performance evaluation, as reported by Chen et al. (1993). They studied the behaviour of three categories of road users; viz non-equipped (unguided) drivers, equipped and totally compliant (guided) drivers, and equipped and partially compliant drivers. They evaluated the DRGS performance under different traffic signal strategies and different levels of congestion and concluded that DRGS strategies have the potential to improve the network efficiency for moderate traffic conditions. At light traffic conditions as well as near jammed traffic congestions, this model showed only insignificant improvement in traffic conditions with the introduction of the DRGS concept.

Fujii et al. (1994) have proposed a macroscopic simulation mode called BOX-MODEL to assess the effectiveness of information based traffic control measures in traffic congestion management. Using three types of road users, they concluded that the traffic congestion in a road network is gradually reduced with the introduction of guided vehicles. However, at high proportions of guided vehicles an increase in the level of congestion was observed.

In general, it has been agreed that DRGS is an effective measure to improve the network performance. In this paper, the proposed evaluation methodology has been applied to compare the effectiveness of DRGS on different sizes of networks. At this stage, however, a comprehensive economic evaluation of DRGS is not feasible because of lack of public domain information about cost components.

3. EVALUATION FRAMEWORK

The present appraisal of DRGS concept is based on the estimation of the possible travel time savings from the proposed system. The operating mechanism of the model, shown in Figure 1, adopts the event update simulation technique. Receiving inputs from network and travel demand data, it first generates journey commencement times for motorists. A probability method has been adopted to identify the origin, destination and motorist type (guided or unguided) of each motorist. Based on motorist type, a route for each motorist is calculated. After the route assignment, the vehicle moves towards its destination following the route determined in the route assignment step. The information in the network and traffic database is updated after every vehicle movement. The simulation continues after the predefined simulation time until all motorists reach their destinations. After the simulation is completed, the analysis sub-model takes control and evaluates traffic and network performance measures using the information stored during the simulation.

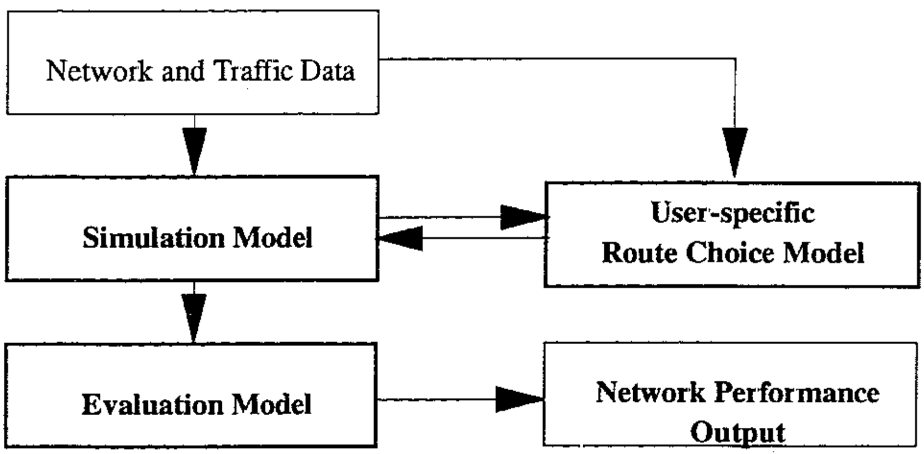


Figure 1 Modelling framework for DRGS evaluation

The model described here is microscopic in nature and treats all motorists on an individual basis. However, when computer memory is limited and travel demand is high, it has provision for combining motorists of similar attributes (journey starting time, origin, destination and vehicle type) into packets. The size of a packet can be controlled, and its limit depends on the travel demand intensity. The concept of vehicle packets has been reported in other simulation applications such as CONTRAM (Taylor, 1990).

Route selection modelling

Routes for guided motorists are recalculated at every intermediate intersection, using a dynamic shortest path method. On the other hand, routes for unguided motorists are calculated based on Burrell's method (Burrell, 1968). This route assignment method includes conceptually sound stochastic features. Thomas (1991) also reported that Burrell's model is suitable for simulation applications. In Burrell's method, the motorists are assumed to make an attempt to travel on shortest routes. However, perception errors related to travel cost of links in the network cause some motorists to select paths other than shortest routes, therefore, traffic is assigned to a number of routes based on the travel time and a reliability measure.

The model reported in this paper is developed from an earlier version (Upadhyay et al., 1994b), and includes important modifications incorporated in two main areas. Firstly, the unguided motorists have been sub-divided as active and passive motorists. Unguided active motorists retain the liberty to modify their routes depending on prevailing traffic conditions on the way to their destination whereas passive motorists have no such flexibility and stick to their initially chosen route. This modification helps in modelling the route choice of the unguided motorist population in a more realistic manner. Unguided active motorists are those who are more familiar with the locality and they are able to assess when a change in a route will be beneficial based on traffic condition faced by them. Secondly, vehicles are monitored on individual basis. This feature enables the model to verify the correctness of route advice during the journey of guided motorists.

Link performance

The link performance computation method has been refined in the current model. Earlier version of the model utilised speed/flow relationship in evaluating the link performance for route calculation purpose. Later, it was acknowledged that speed/flow relationship curve which is parabolic in nature, may lead to ambiguous link performance results unless traffic density or average speed is available. For example, a flow of 100 veh/h may represent light traffic, or a severe traffic jam depending on the part of the parabolic curve considered. This uncertainty has been removed in the present model by using speed/density relationship which is linear in nature. However, the model has provision to incorporate any speed/flow/density relationship such as Bureau of Public Roads (Thomas, 1991) and Davidson's speed/flow (Davidson, 1966) relationship.

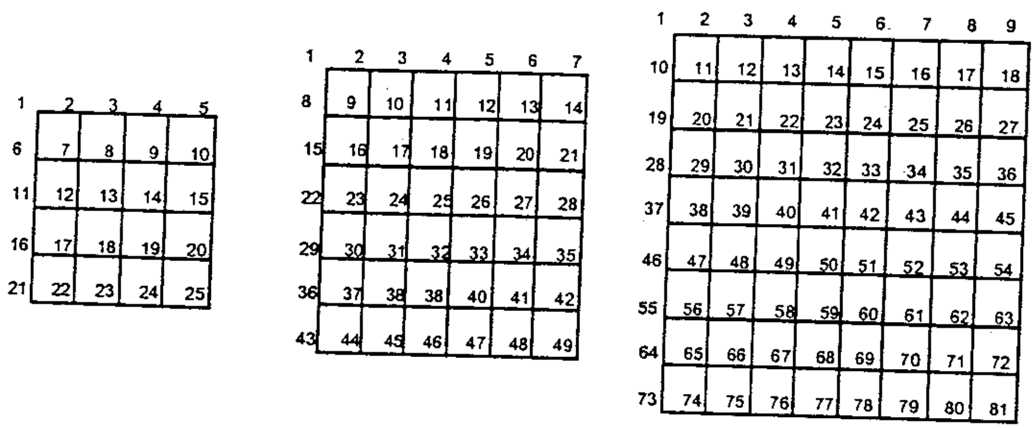
Intersection delay

The model reported in this paper is able to incorporate intersection delays under fixed signal timing strategy. It has been acknowledged that intersection delays contribute a significant proportion in total journey time in urban areas. Also, intersection delays may be significantly reduced by using vehicle actuation and network optimisation strategies. However, in this research, intersection delays were ignored. It is considered better to handle intersection delay impacts as a separate issue of relatively broader significance. It is planned to include a number of signal optimisation strategies in order to make the model versatile for realistic applications.

4. MODEL APPLICATION

In this paper, the evaluation model has been applied on three different size road networks under different proportions of guided motorists. The objective of the analysis is to investigate the DRGS performance with respect to network size and its implications for guided and unguided motorists.

Three square grid networks referred to as small, medium and large network are selected for the analysis. The total number of nodes in these networks are 25, 49 and 81, while the total number of one-way links are 80, 168 and 288 respectively. Figure 2 shows the schematic representation of these networks. Other network parameters such as link length, link capacity and free flow speed are kept the same for all links in the three networks.



(a) small network (b) medium size network (c) large network

Figure 2 Schematic representation of networks

The travel demand matrix consists of 8x8 cells in the small network. For the medium and large networks the matrix dimensions are 12x12 and 16x16 respectively. For each network, the origin and destination nodes are chosen from the outer most grid. For example, in the small network, nodes numbered 1, 3, 5, 11, 15, 21, 23 and 25 act as origin and destination nodes. In the medium network, origin and destination nodes are numbered as 1, 3, 5, 7, 15, 21, 29, 35, 43, 45, 47 and 49. Similarly, for the large network, origin and destination nodes are numbered as 1, 3, 5, 7, 9 ... 73, 75, 77, 79 and 81.

Initially, each network was investigated under three travel demand scenarios represented by load factors of 1.0, 1.5 and 2.0 representing low, medium and high travel demand respectively. For each network the travel demand had been assigned in such a way that load factor 1.0 causes the same amount of overall traffic congestion in all three networks. However, in this paper, only the medium level of demand has been discussed. It is acknowledged that the effect of high level of travel demand needs further investigation (Upadhyay et al., 1994a).

5. RESULTS AND ANALYSIS

Simulation runs were performed for each network under guided motorist proportions of 0, 10, 20, ... 80, 90 and 100% and performance indicators such as mean travel speed, link travel time and travel time savings were computed for guided and unguided motorists. Network-wide traffic density was also evaluated to assess the DRGS performance from congestion management point of view.

Journey time

Figure 3 shows the mean journey time for guided motorists against their proportion in the traffic stream for all the three networks. The journey times for guided motorists are of the order of 7, 9 and 12 minutes in small, medium and large network. Mean journey time experienced by these motorists appears to insensitive to the size of their proportion. This observation is in agreement with earlier findings reported in Upadhyay et al. (1994b) and the general insensitivity of the level of savings to the size of guided motorists population is beneficial from marketing point of view as the innovation can be seen as consistent in the benefits it can bring irrespective of the number of subscribers to such systems.

Mean link travel speed

Figure 4 shows the mean link travel speed (km/h) for guided motorists. It is evident from the plots that mean travel speed experienced by DRGS subscribers is of the order of 50 km/h for three networks considered in the study. Similar curves have been obtained for low and high travel demand, but not shown here. It appears that mean travel speed is not sensitive to the proportion of guided motorists either. By combining the mean journey time and speed it could be observed that mean travel distance for guided motorists is also insensitive to their proportion in a particular network. Comparison of mean travel distance for guided and unguided motorists indicates that mean travel distance is of the same order of magnitude for both types of motorists. This observation ensures that although DRGS attempts to direct guided motorists to minimum travel time routes it keeps in mind to avoid excess travel distances.

Mean link travel speed for unguided motorists is shown in Figure 5. It is clear from the graphs that mean link travel speed for unguided motorists increases as the proportion of guided motorists increases. The growth in the mean speed is relatively

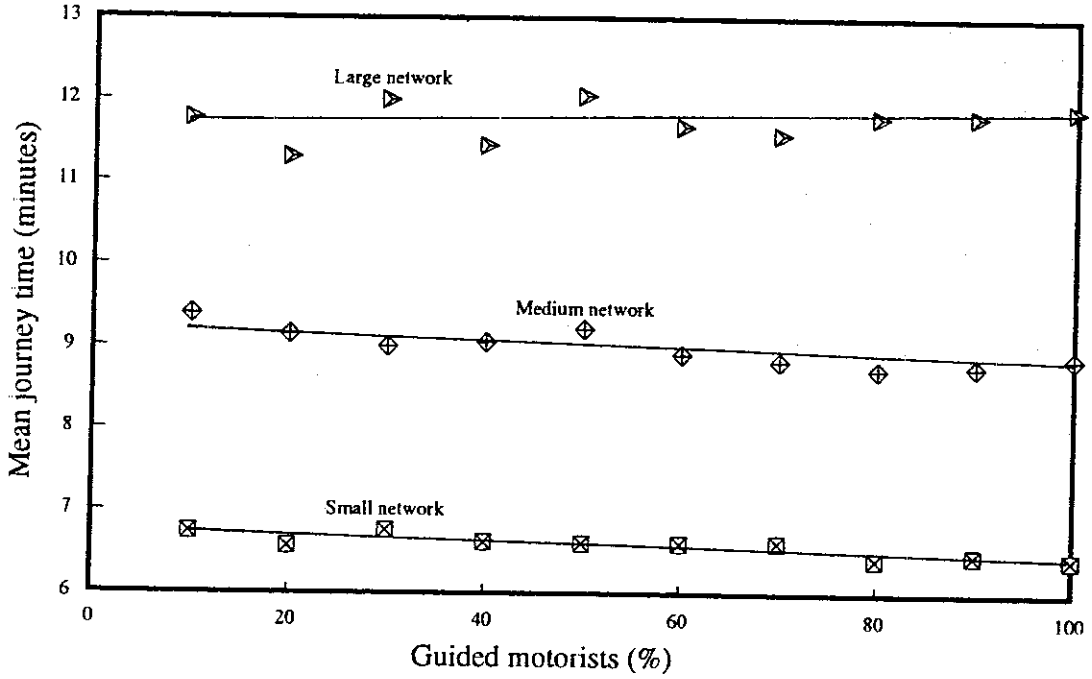


Figure 3 **Mean journey time for guided motorists**

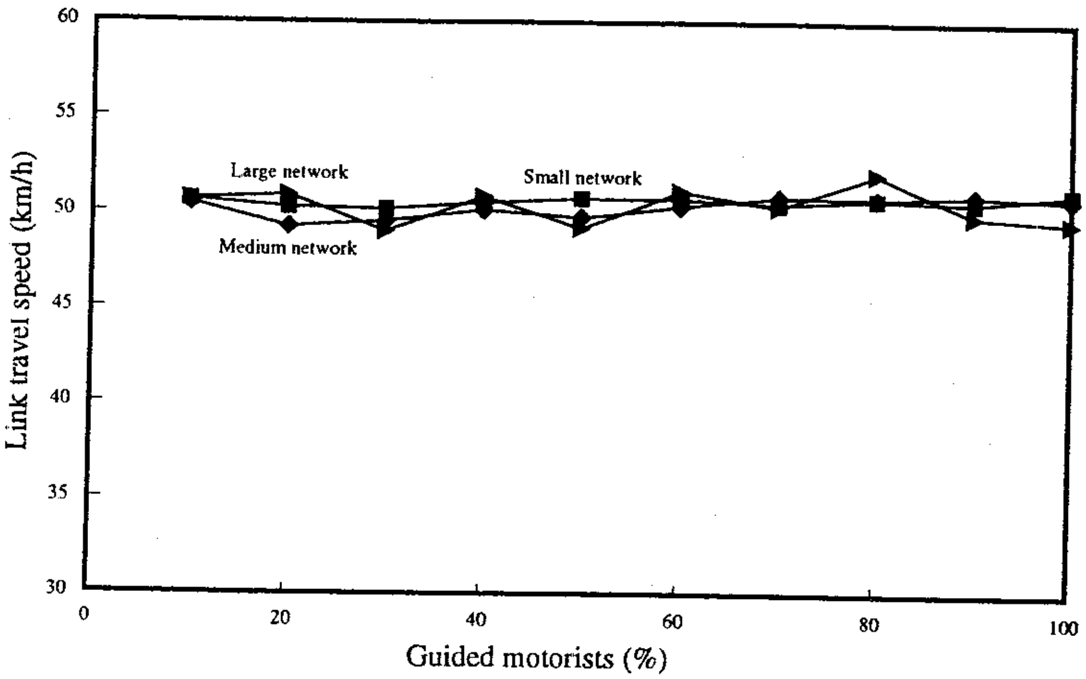


Figure 4 **Mean link travel speed for guided motorists**

high in the first half of the curve indicating better performance of unguided motorists with the initial introduction of DRGS. The lowest travel speed has been observed for the large network which shows that unguided motorists are worse off in a large network due to increased difficulty in identifying less congested routes. This phenomenon needs to be further investigated. With higher proportions of guided motorists the difference in mean travel speed narrows among the networks. At 90% of guided motorist proportion, the mean travel speed is of the order of 50 km/h compared to about 30 km/h with no guided motorists. The trend of these graphs confirms the expectation that DRGS distributes the traffic evenly over the network leaving enough uncongested routes for unguided motorists. Even distribution of traffic eventually results in overall improvement in the network performance.

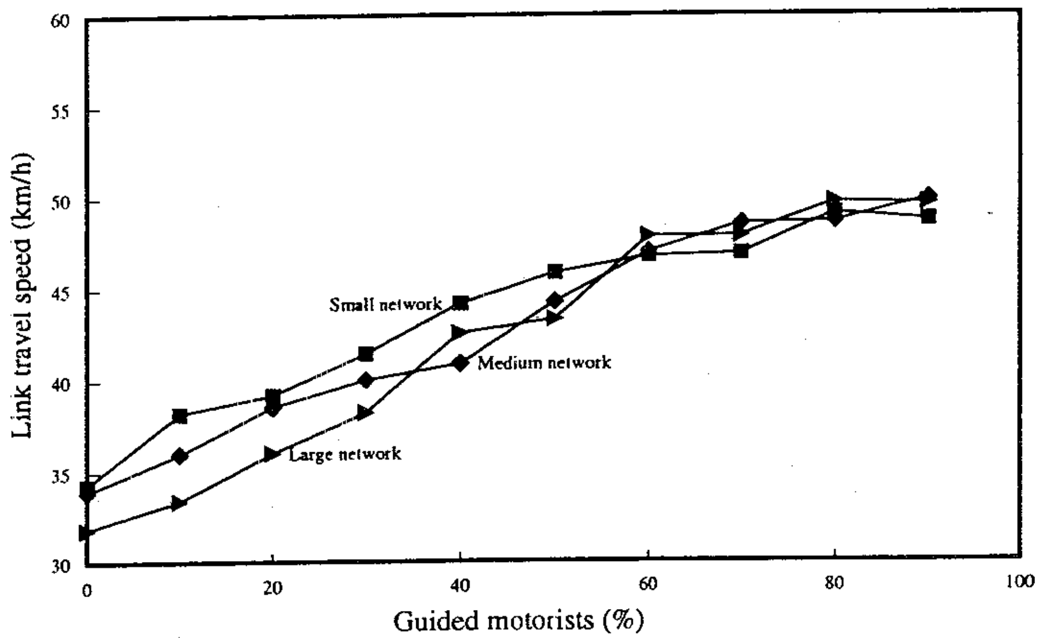


Figure 5 Mean link travel speed for unguided motorists

Mean travel time savings

Figure 6 shows the estimates of mean travel time savings for guided motorists against their proportion. These savings have been estimated compared to basic travel time with no guided motorists. Two observations can be made from these plots. Firstly, the order of magnitude of travel time savings is relatively consistent at about 30% showing insensitivity to the proportion of guided motorists. This observation is in agreement with earlier findings as reported in Upadhyay et al. (1994b). The mean link travel speed also showed similar insensitivity. Secondly, the mean travel time savings are marginally higher for large network whereas these savings are more or less the same for small and medium network. This observation is of importance from network size application point of view as DRGS concept appears to be more effective in relatively large network. However, more analyse of various network sizes is required to further investigate this particular trend.

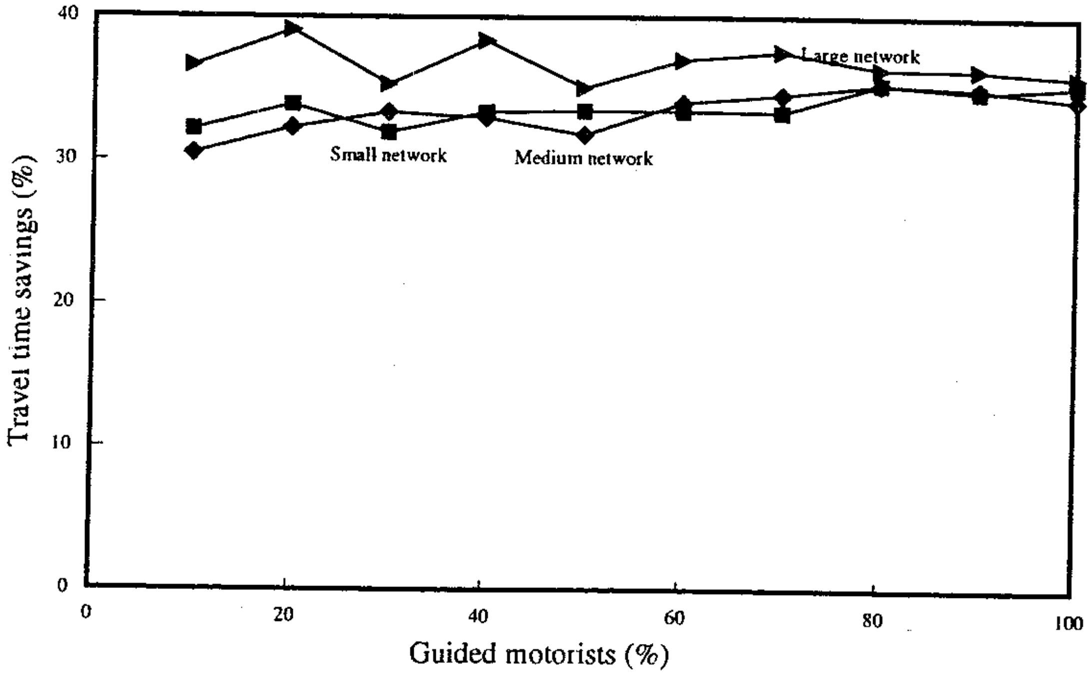


Figure 6 Mean travel time savings for guided motorists

Mean travel time savings for unguided motorists are shown in Figure 7. It is not possible to identify a significant impact of network size on this group of motorists. However, it is important to notice that travel time savings keep increasing for unguided motorists with more and more guided motorists introduced into the traffic stream. From the user point of view the difference in the percentage savings as shown in Figures 6 and 7 denotes the direct travel time benefits that motorists can achieve by subscribing to the DRGS concept. This difference is important in pricing the DRGS from the point of view of developers and transport planners. In the large network, at 90% proportion of guided motorists, the travel time savings of unguided motorists are unexpectedly more than that of guided motorists (see Figures 6 and 7) indicating that unguided motorists are performing slightly better than guided motorists. However, comparing the mean link travel speed (Figures 4 and 5) for both classes of motorists it is clear that the mean speed for guided motorists is greater than that for unguided motorists. In fact, the trips in larger network are ranging from 2 km to 16 km and the origin and destination to both guided and unguided motorists are assigned using a probability method. It appears that the smaller mean trip times and subsequently higher travel time savings for unguided motorists at 90% guided motorists scenario are due to those randomly assigned shorter trips to unguided motorists.

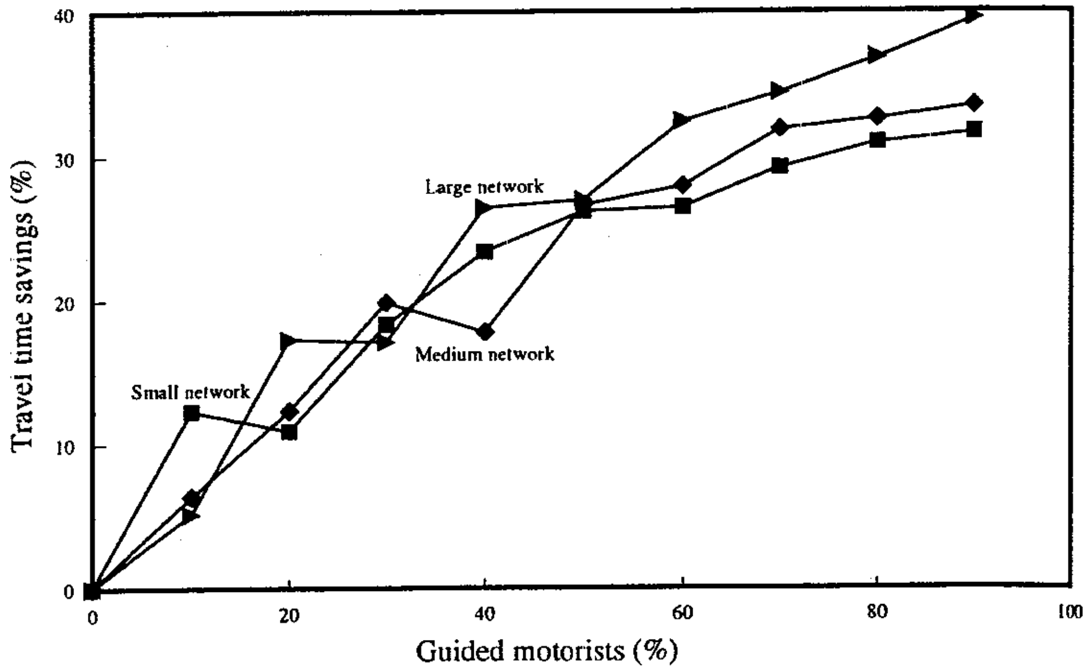


Figure 7 Mean travel time savings for unguided motorists

Traffic congestion

Improvement in average link performance is analysed using a plot of average traffic density (veh/km) against the proportion of guided motorists (Figure 8). The mean traffic density reduces rapidly with initial increase in guided motorist proportion. A less significant reduction is observed beyond 60% level of guided motorists proportion. Similar pattern of reductions has been observed in the standard deviation of traffic density during the simulation. This confirms that DRGS distributes the traffic uniformly through the network and may reduce network-wide congestion. Similar observations were provided in detail by Upadhyay et al. (1994c). Also, the reduction in traffic density is comparatively high in the large network. This is in agreement with the previous evidence that DRGS concept could be more beneficial in larger networks.

In summary, the comparison of mean journey time, link travel speed, travel time savings and traffic density has shown that the DRGS is beneficial for all sizes of networks. Some of the observations have indicated that DRGS is relatively more effective in large networks.

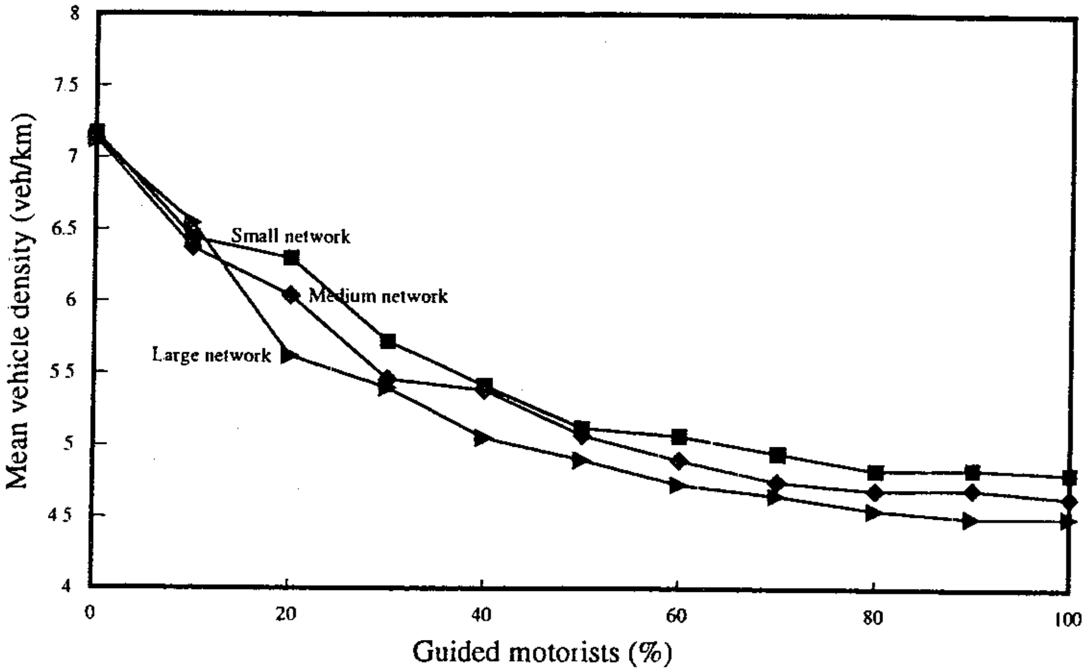


Figure 8 Network-wide average traffic density

6. CONCLUSIONS

Further enhancement and application of the DRGS evaluation model being developed at University of New South Wales have been reported in this paper. The model adopts simulation techniques and is microscopic in nature. The model has been applied to study DRGS impact on different size networks. Three square grid networks of different sizes have been chosen to study the mean link travel speed and travel time savings for guided and unguided motorists. Investigations do not show a clear pattern of DRGS relationship with network size. The investigation of travel time savings and speed partially indicated that DRGS could be more effective in relatively large networks, but further analysis of various size networks is required to justify this finding.

The effect of DRGS on congestion management has also been discussed. The results indicate that DRGS can be potentially more effective in reducing the network-wide congestion by distributing the traffic in an efficient manner. Hence the DRGS concept provides a technological approach to transport reform. The methodology discussed in this paper allows planners to quantify potential benefits and determine appropriate pricing standards.

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