DYNAMIC ROUTE GUIDANCE: SOME ASPECTS OF OPTIMISATION

Nick HOUNSELL, Fraser MCLEOD and Mike MCDONALD
Transportation Research Group
University of Southampton
SOUTHAMPTON - U.K.

1. INTRODUCTION

Increasing car ownership and demand for travel in urban areas is leading to significant traffic congestion in many cities of the world. The provision of additional road capacity is often severely constrained in these cities, and such construction is, in any case, unlikely to be "the answer" to congestion, as it often causes a release of suppressed demand and a continuation of congested conditions. In these circumstances, it is important that best use is made of the existing road space by implementing efficient traffic management and control techniques. Traffic responsive Urban Traffic Control Systems, such as SCOOT (Hunt et al, 1981) are one example of recent systems which have achieved improved efficiency.

A further improvement in traffic efficiency in urban areas could be achieved by the introduction of "Informatic" systems, such as dynamic route guidance (DRG) to reduce route choice "inefficiency". The ALI-SCOUT DRG system (V. Tomkevitsch, 1986), operational in Berlin, is one such example and increased activity in Europe, via the DRIVE programme, will result in a range of systems appearing over the next decade.

Dynamic Route Guidance is a new technology which, if widely adopted, could have a significant impact on network traffic conditions. The relative benefits of different systems to guided drivers and the effects on overall network performance are clearly important issues. The investigation of these issues prior to implementation, and of other "aspects of optimisation" such as routeing strategies, requires the use of simulation modelling incorporating dynamic traffic assignment. The following sections of this paper describe the main attributes of DRG modelling developments at the University of Southampton, and preliminary application of the model to investigate aspects of DRG optimisation.

The work described here has been undertaken within the DRIVE project "CARGOES" (Siemens et al, 1991), which considered the integration of dynamic route guidance and traffic control systems, and within a "rolling programme" of research being undertaken by the Universities of Leeds and Southampton into "Fundamental aspects of dynamic route guidance", sponsored by the Science and Engineering Research Council. Work in this area is continuing in the rolling programme and within the sub-project "MARGOT" which is part of the LLAMD consortium working within DRIVE to implement advanced telematic systems in a number of European cities.

2. DYNAMIC ROUTE GUIDANCE

Dynamic route guidance is a system aimed at guiding drivers on the optimum route to their destination, taking account of existing/forecast traffic conditions, with guidance being provided by in-vehicle units. Existing architecture (e.g. as in Berlin) incorporates infra-red beacons at key intersections, which receive data from equipped vehicles (e.g. preceding link journey times) and transmit optimum routes, which are regularly updated. Route calculations are undertaken centrally, based on "static" network information and real-time data mainly from equipped vehicles. There is thus a two way communication link between equipped vehicles, beacons and the DRG control centre.

Other forms of DRG are also now being installed. These include DRG using cellular radio concepts, in which real time information (e.g. link journey times) is "broadcast" to vehicles, with route calculations being undertaken in the vehicle, rather than centrally.

3. MODELLING REQUIREMENTS AND DEVELOPMENTS

The simulation of DRG systems allows the performance of the system and its network effects to be evaluated in controlled conditions at various levels of "take-up" (or "penetration") and can aid system optimisation.

The requirements for simulating DRG depend on the level of investigation being carried out, but key aspects include:

(i) The distinction between guided and unguided vehicles of different types, with each category having user-defined assignment (routeing) criteria.

(ii) The modelling of networks of sufficient size for assessment, but with sufficient detail to model all typical urban network and control features (junction types, UTC, one-way streets, etc.). A DRG network of restricted density (e.g. to main roads only) should also be able to be considered.

(iii) The realistic modelling of traffic performance in conditions of time-varying traffic demand (including congestion, blocking-back effects and so on) and traffic incidents.

(iv) The modelling of the operation of DRG beacons (which transmit the control strategies) including computing/ communications delays and feedback from vehicles of link times.
(v) The capability of examining user-optimum and network- optimum control strategies.
(vi) A realistic representation of driver response to guidance advice.
(vii) The provision of outputs for detailed investigation (routes, link flows, delays, etc.) and summary statistics for evaluation.

These requirements have led to the development at the University of Southampton of RGCONTRAM (Route Guidance CONTRAM). CONTRAM (Leonard et al, 1989) is a dynamic assignment model usually used for the evaluation of traffic management schemes in urban areas. It has the necessary detailed assignment characteristics and traffic modelling to be a base model for developing DRG functions. It is particularly suitable because of its "packet" structure of assignment and because of its time dependent modelling of traffic demand and queueing, including congestion and "blocking back".

RGCONTRAM has been developed to provide a mimic of the key attributes of DRG systems, based initially on ALI SCOUT, reflecting the beacon operations and routeing processes involved. However, it is sufficiently flexible, and being further developed, to allow different operations and systems to be evaluated. The model compliments the Route Guidance Simulation model ROGUS (Stevens and Hounsell, 1992) developed by the UK Transport and Road Research Laboratory, which has incorporated aspects of CONTRAM.

4. OPTIMISATION ISSUES

Some aspects of optimisation which can be addressed by simulation models such as RGCONTRAM include:

* The beacon density and update frequency requirements to provide sufficiently dynamic routeing.
* The routeing criteria and strategies required in "normal" and "abnormal" traffic conditions
* The effects of increasing DRG penetration on guided and unguided drivers
* The sensitivity of system performance to factors such as journey time forecasting, driver behaviour, etc.
* The integration of DRG with other systems, such as UTC.

This is an inexhaustive list, but serves to illustrate the important role simulation should play in system design and evaluation.

5. EXAMPLES OF APPLICATIONS

The following sections describe examples of current applications of RGCONTRAM.

5.1 Beacon density

The density (spacing) of beacons in a network determines the frequency with which drivers will receive new, improved routes as they travel through the network. Thus, increased density results (on average) in better routes, although there is increased costs of infrastructure, communications and data processing. In general, the greater the variability in link travel times the greater will be justification for denser beacon spacings. Figure 1 illustrates a relationship between DRG journey time savings and increasing beacon density in a network of 150 junctions with moderate congestion. This figure applies to a situation with a typical peak profile of demand and travel times, but repeatable conditions between days. A steeper trend would be expected in Figure 1 if between-day variability were included; this is currently being evaluated. Clearly, results such as in Figure 1 could be used within a cost-benefit framework to determine optimum beacon density.

5.2 DRG network

The guidance network may be a subset of the total road network if, for example, minor roads are excluded. Such exclusion could be to reduce the costs of the DRG system (network definition, database, etc.) or because of a policy decision/constraint to reduce traffic on certain roads. RGCONTRAM contains a facility for simulating this by applying a user-specified "impedance" (i.e. link cost multiplier) to selected links when routes are calculated for guided vehicles. A high impedance causes these links "never" to be selected while a lower impedance would reduce their use. Figure 2 shows an example of the sensitivity of journey time savings to increasing levels of link impedance, for the condition where all links are available for DRG and for a 20% DRG penetration scenario. In this case, an impedance factor below 1.5 would be required to maintain worthwhile DRG savings, although the overall reduction in traffic flow on minor roads was only 1-2%. The use of this technique also has implications on drivers acceptance of advice.

5.3 Routeing Criteria

DRG systems such as ALI-SCOUT are currently offering "optimum" routes to drivers on the basis of minimum journey time for the user. While this criterion is of importance to most drivers, there is evidence (Bonsall, 1990) that a range of other route choice criteria exist between drivers, such as "reliability of journey time" and "avoidance of congestion". It is also likely that many drivers would wish to minimise their travel cost, but use travel time as a proxy for cost as it is easier to perceive.

RGCONTRAM provides a convenient method for evaluating the effects of different route criteria in the guidance function, by adopting the following expression for the perceived cost of travel (C) on each link.

$$C = aL + bT + cLV^2 + dS + eD + fP + gR + hM \quad \ldots\ldots \quad 1$$

where L = link length
T = travel time
V = speed
S = number of stops
D = delay
P = price (e.g. toll, environment)
R = risk (e.g. accident rate)
M = marginal cost
$a \ldots\ldots h$ = co-efficients

The flexibility of equation 1 allows factors other than journey time to be used for route guidance, and the resulting assignments can be evaluated in terms of the routes offered, the journey times on these routes (and, therefore, the likely acceptance of the guidance) and overall network effects. For example, there are likely to be "community" benefits by advising routes which are optimised in terms of safety, fuel consumption and the environment and weight can be given to these parameters by adopting suitable co-efficients in equation 1. The skill will be in incorporating these parameters while still maintaining routes accepted by users.

5.4 Multi-routeing

DRG currently provides a single "best" route from each beacon to the destinations served by that beacon, with route updating every 5 minutes. This is satisfactory for low levels of DRG penetration when the assignment will have little effect on link flows and delays. This will not hold at high penetration levels, however, and the maintenance of network stability will require the use of multi-routeing.

Figure 3 illustrates one example of how journey time savings might reduce with increasing DRG penetration, if the single routeing strategy is maintained. As DRG penetration increases, routeing methods may have to evolve as illustrated in Figure 4, to maintain optimality. Thus, with increasing DRG penetration, current single routeing could evolve to multi-routeing solutions provided by a dynamic assignment model and finally to system optimum, rather than user optimum, solutions. Of course, the diversification of criteria in the guidance function would also tend to produce multi-routeing.

5.4 Traffic incidents

DRG is likely to be particularly beneficial when traffic incidents, such as accidents or breakdowns, cause unpredictable congestion. However, the usual assignment procedures become inappropriate. Routes adopted by **unguided** drivers will be neither "normal" routes, nor a re-assignment to optimum routes, as drivers will have insufficient knowledge to re-optimise. To provide more realistic modelling, a logic has been implemented in RGCONTRAM such that unguided drivers follow normal routes but can re-assign at any junction when encountering an unexpected queue ahead, subject to there being a reasonable alternative route. Key user-specified parameters of this logic include:

(i) The percentage of drivers who will not divert (e.g. those who are unfamiliar with the network).
(ii) The number of diversions allowed.
(iii) The maximum ratio of cruise time for the alternative route to that for the normal route, which describes whether or not an alternative route is accepted.

The logic described above for unguided drivers is also available for **guided** drivers in RGCONTRAM. However, if all guided drivers follow guidance, the logic is not used. There is evidence (Bonsall et al, 1991) that for "directive" guidance without supporting information (e.g. ALI-SCOUT type guidance), some guided drivers will reject guidance in incident situations where guidance may appear perverse (e.g. where guidance is away from the normal route, or where it is towards a link containing a queue). Clearly a good behavioural model of driver response is important in these situations.

The development of optimum strategies for guided vehicles is now being considered, related to incident characteristics (location, duration, severity, etc.), network congestion and so on.

5.4 Integration with UTC

Research within the DRIVE project CARGOES highlighted the importance of integrating DRG and UTC systems, if maximum benefits are to be obtained from each. At low levels of DRG penetration, the integration would be mainly "low level", comprising an exchange of relevant data between the systems for each others advantage. For example, a traffic responsive UTC system such as SCOOT would benefit from the use of DRG data for model validation and for providing a strategic view of network conditions outside of SCOOT's immediate areas of control. In reverse, DRG would benefit from SCOOT's on-line information on link journey times, spare capacity and so on. An example of these integration concepts for "co-operating" systems is given in Figure 5.

At higher levels of DRG penetration, a higher level of integration can also be envisaged, involving the exchange of control strategies and, ultimately, the derivation of unique optimised solutions to vehicle routeing and signal timings. An image of the key elements and their integration in such a system is illustrated in Figure 6. The realisation of such a system is a long term goal and its evaluation will require considerable further developments of simulation models and optimisation techniques.

6. CONCLUDING COMMENTS

The "success" of dynamic route guidance in terms of its take-up is likely to rest on a number of key issues, particularly the cost of the system to the operator and driver, the facilities offered in addition to route guidance, the travel characteristics of the driver (e.g. number of trips, variety of destinations) and the perceived quality of the guidance offered. On the latter point, it will be important that drivers gain and retain confidence in the system, so that they will largely accept the advised routes even when these routes may appear perverse. This will place high expectations on DRG systems which claim to provide optimum routes for any traffic conditions. The issue of "optimisation" then becomes even more important to guided drivers than, say, optimisation of signal settings, where all drivers are affected.

Recent research has highlighted some situations where drivers may reject advice. This rejection should be minimised by (i) providing information as well as guidance to drivers, particularly where unusual routes are recommended (e.g. because of an accident) and (ii) providing optimum (or near optimum) routes, so that drivers perceive a high quality system. Point (ii) requires optimisation of a variety of elements, for which simulation modelling, incorporating realistic models of drivers decisions, will be an important aid.

The modelling of medium-high penetration scenarios presents further problems caused by the significant changes in network operating conditions which are likely over the next 10-20 years and beyond. In particular, a variety of RTI functions and expert systems are likely to be operating, such as traffic information systems, VMS, congestion control, automatic incident detection, road congestion pricing and so on. In this scenario DRG "optimisation" will have to be considered as part of the integrated system.

Field trials will play a vital role in system optimisation, both by providing a direct evaluation of system performance and by providing important data for simulations which will be used to develop "next generation" systems. The proposed initiatives in DRIVE are therefore of particular importance.

7. REFERENCES

Bonsall, P.W. and Joint, M.J. "Evidence on Drivers' Reactions to In-vehicle Route Guidance Advice", ISATA Conference on Road Transport Information-Intelligent Vehicle-Highway Systems, Florence, 1991.

Bonsall, P.W. and Parry, T. "Drivers Requirements for Route Guidance", Third International Conference on Road Traffic Control, Institution of Electrical Engineers, London, 1990.

Hunt, P.B. et al. "SCOOT - A Traffic Responsive Method for Co-ordinating Signals", Department of Transport, Transport and Road Research Laboratory, Report LR 1014, Crowthorne, 1991.

Leonard, D.R. et al. "CONTRAM: Structure of the Model", Department of Transport, Transport and Road Research Laboratory, Report RR 178, Crowthorne, 1989.

Siemens et al. "The Integration of Dynamic Route Guidance and Traffic Control Systems", Final report of the CARGOES consortium to DRIVE, Brussels, 1991.

Stevens, A. and Hounsell, N.B. "Simulation Modelling of Route Guidance Control Strategies", ISATA Conference on Road Transport Information-Intelligent Vehicle-Highway Systems, Florence, 1992.

V. Tomkevitsch, R. et al. "ALI SCOUT - A Universal Guidance and Information System for Road Traffic", Second International Conference on Road Traffic Control, Institution of Electrical Engineers, London, 1986.

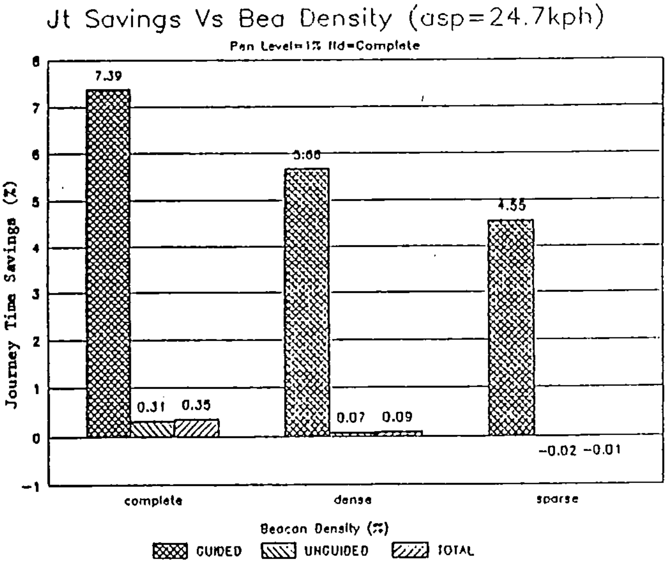

Figure 1 Example of the effects of beacon density on journey time savings due to route guidance (1% DRG penetration level)

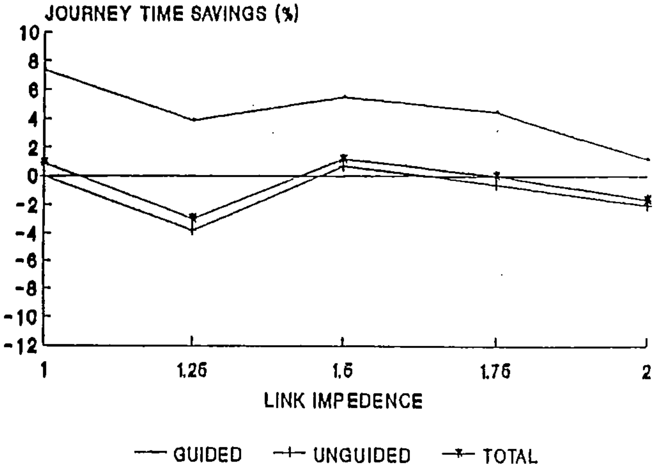

Figure 2 Example of the effects of increasing link impedance on minor roads on journey time savings due to route guidance (20% penetration level)

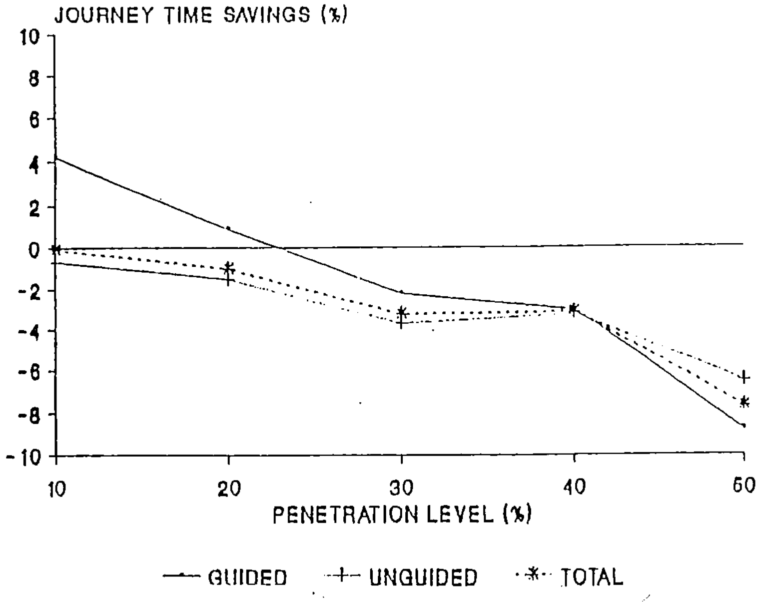

Figure 3 Example of effects of increasing DRG penetration on journey time savings if single routeing is maintained

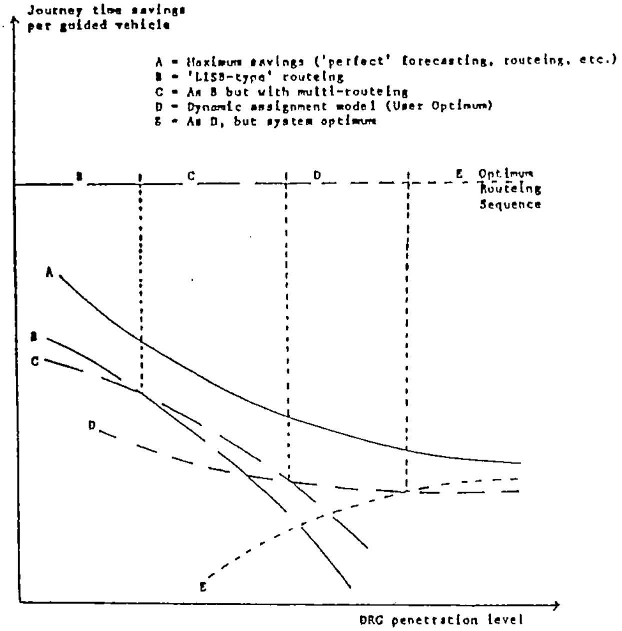

Figure 4 Concept of DRG routeing evaluation with increasing DRG penetration

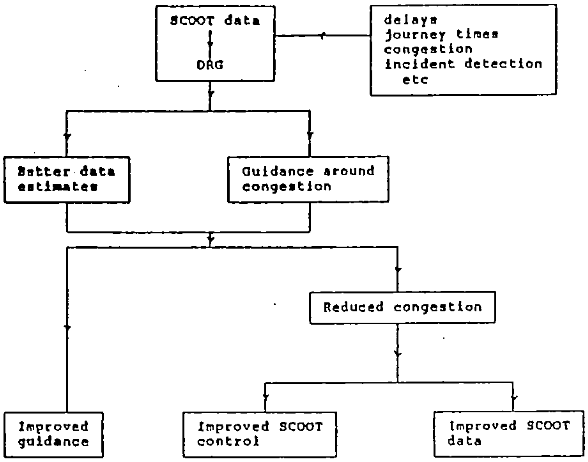

Figure 5 SCOOT/DRG integration - an example

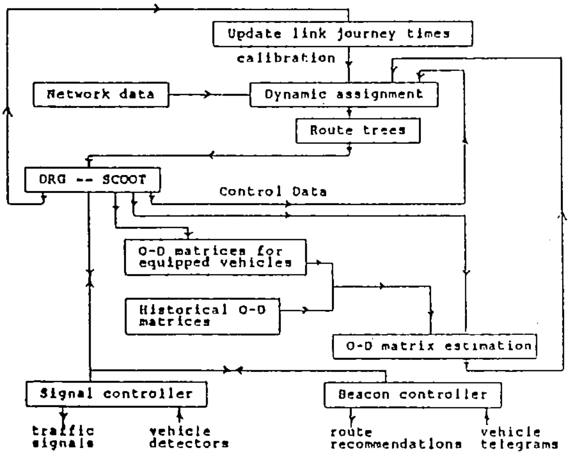

Figure 6 Example of high level integration at high penetration