THE EFFECTS OF DYNAMIC ROUTE GUIDANCE IN LONDON

by B Stoneman

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<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>1</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. The traffic assignment model</td>
<td>1</td>
</tr>
<tr>
<td>3. The First study</td>
<td>2</td>
</tr>
<tr>
<td>3.1 Network performance</td>
<td>2</td>
</tr>
<tr>
<td>3.2 Geographical distribution of network traffic</td>
<td>2</td>
</tr>
<tr>
<td>3.3 Restricting guided traffic to Motorway and A-class roads</td>
<td>4</td>
</tr>
<tr>
<td>3.4 The density of roadside communication beacons</td>
<td>4</td>
</tr>
<tr>
<td>4. The Second study</td>
<td>4</td>
</tr>
<tr>
<td>4.1 Restricted network</td>
<td>4</td>
</tr>
<tr>
<td>4.2 Accident costs</td>
<td>5</td>
</tr>
<tr>
<td>4.3 Inter-Peak tests</td>
<td>6</td>
</tr>
<tr>
<td>4.4 Increased traffic demand</td>
<td>7</td>
</tr>
<tr>
<td>5. Conclusion</td>
<td>8</td>
</tr>
<tr>
<td>6. Acknowledgements</td>
<td>8</td>
</tr>
<tr>
<td>7. References</td>
<td>8</td>
</tr>
</tbody>
</table>
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ABSTRACT

Advances in technology have enabled dynamic route guidance systems to reach the stage of implementation on the road network. Dynamic route guidance measures vehicle journey times and flows through a road network and calculates and conveys to individual drivers information on the best route to a destination. A small scale trial of route guidance systems has been demonstrated and shown to work satisfactorily in Great Britain (Catling, 1991) and Germany (Sparmann, 1989).

This report summarises two studies that estimate the impact of introducing dynamic route guidance to the London area bounded by the M25-orbital motorway. The studies used a large scale traffic assignment computer model (DTp, 1987), and comprised a number of tests with varying proportions of guided traffic. The tests included: estimates of the benefits for guided and unguided traffic in the peak period and the inter-peak period, the effect of increased traffic demand on the network, the restriction of guided traffic to strategic sub-networks, and potential accident cost savings.

1. INTRODUCTION

The Transport Research Laboratory has undertaken a programme of research into the possible impacts of vehicle route guidance, with the results published as a series of reports (TRRL 1989(a), (b), (c), (d), (e)). The purpose of this report is to summarise the results of two computer modelling studies which estimated the impact of introducing a dynamic route guidance system to the London road network. A large scale traffic assignment computer model was used for both studies.

The first study (TRRL, 1989(a)) considered:
- The network performance for increased levels of guided traffic.
- The geographical distribution of traffic over the road network.
- The effect of restricting guided traffic to Motorway and A-class roads.
- The density of roadside communication beacons which provide dynamic route information to guided traffic.

The second study (TRRL, 1990) considered:
- Restricting guided traffic to Motorway, A and B-class roads.
- Accident savings attributable to route guidance.
- Benefits of route guidance to traffic in the inter-peak period.
- Changes to benefits with increased traffic demand.

2. THE TRAFFIC ASSIGNMENT COMPUTER MODEL

The London Transportation Studies (LTS) traffic assignment model was used to study the effects of dynamic route guidance on the London road network. It is a large traffic model by common standards, comprising 7000 nodes and 16000 one-way links within the London area bounded by the M25 Motorway. Traffic data for the model was obtained from the 1981 Greater London Transportation Survey (GLTS-81).

An essential requirement of the model was to allow vehicles to be assigned to routes as guided and unguided vehicles. An assignment method was required to assign guided vehicles to the most suitable routes based on comprehensive knowledge of current link costs. Unguided vehicles would not have the benefit of this information for route planning.

The principles of the method adopted were as follows:

(a) Unguided traffic is assumed to base route planning decisions on a perception of network costs which are representative of average travel demand and associated network conditions. Unguided traffic does not change route despite variations in link costs from which routes were planned.

(b) The average demand is represented by the car and private light vehicle average morning peak hour matrix. The assignment of this matrix to the LTS network is assumed to represent this average situation.

(c) The demand on any actual day will vary from this average, and a simulation of this situation is obtained by random perturbation of the trip matrix. This randomised matrix is assigned to the highway network using the routes calculated for the average day. This use of non-optimal routes causes the network costs to increase. This is assumed to represent an overall level of inefficiency in the network which might arise on an actual day.
The unguided vehicles are constrained to use the average day routes.

The guided vehicles are optimally assigned to routes through the network after the unguided vehicles.

Guided traffic has the opportunity to choose routes which are optimum with respect to the actual day’s demand, and to the actual day’s routeing behaviour. The unguided traffic has neither of these opportunities. This assignment method does not take into account traffic variations unrelated to traffic demand such as incidents, parking, and roadworks. As dynamic route guidance is intended to respond to such variations, the assignment method will give a conservative view of estimated benefits.

The degree of perturbation of traffic flow that occurs on actual road links has been observed by separate studies (LTS-21), (WLAS, 1987), and gave daily variations in link flows of between 5% and 11% (coefficient of variation). The model perturbation was adjusted to be broadly consistent with these observations.

The absolute benefits of dynamic route guidance predicted by the model, will be affected to some extent by the different levels of traffic flow variation assumed for the model. Therefore, the distribution of the benefits predicted by the model are a better indicator of the effect of route guidance, than the absolute benefits.

3. THE FIRST STUDY

3.1 NETWORK PERFORMANCE

The network performance was assessed for 10%, 20%, 30% and 100% levels of guided traffic. The results shown in Figure 1, indicate that as the proportion of guided vehicles increases to 100%, the overall network performance or efficiency increases. The number of vehicle kilometres travelled reduces by between 0.2% to 1.3%, the vehicle hours reduce by between 2.5% to 6.2%, with average vehicle speed increasing by between 2.4% to 5.3%.

The distribution of benefits between guided and unguided vehicles in terms of average journey time is shown by Table 1. With 10% guided traffic, the average journey time for the guided traffic reduces by 6.9%. As the percentage of guided traffic increases, the average journey time saving to the guided users remains approximately the same, with all vehicles guided the benefit is 6%.

There are benefits for the unguided traffic as guided traffic transfer to more efficient routes. With 10% guided traffic the average journey time for unguided traffic is reduced by 2.2%. As the level of guided traffic increases the benefit to the unguided traffic also increases. At the 30% guided level, the average journey time saving for unguided traffic increased to 3.1%, approximately one half the time savings for guided traffic.

3.2 GEOGRAPHICAL DISTRIBUTION OF NETWORK TRAFFIC

The above results indicated the effect of route guidance on the overall network performance in terms of vehicle kilometres travelled, journey time and average speed. The geographical distribution of these effects is also of interest, and results are available for: Inner London, Outer London, and the London peripheral area (the immediate area beyond the Outer London boundary, including the M25-Motorway).

The percentage changes in vehicle kilometres travelled for the different London regions are shown in Figure 2. The greatest change occurs in Inner London. At the 10% level of guided traffic, vehicle kilometres driven decreases
The percentage change in vehicle kilometres by region, for different levels of guided traffic is shown in Figure 2. The effect is less for Outer London with reductions between 0.3% and 1.2%. However, for the London peripheral area there is a small increase which rises to 0.5% when all traffic is guided. This will include the effect of traffic using the M25 motorway to avoid congested areas.

A similar effect occurs with average traffic speed, shown in Figure 3. There are greater improvements in the Inner London area, with average speed increases of 3.6% at the 10% level of guided traffic to 7.4% when all traffic is guided. Outer London has increases in speed between 1.9% and 4.4%, with the London peripheral area having a modest increase of between 0.4% and 1.2%.

The results show that the geographical distribution of the effects of route guidance are not uniformly spread across the London road network. Benefits in terms of network speed and traffic level were considerably greater (approximately double) in Inner London than in Outer London.

The motorways and A-class roads represent the primary road network and carry approximately two-thirds of the total traffic. Non-primary roads carry the remaining traffic. The effect of route guidance on vehicle kilometres travelled for primary and non-primary roads is shown in Table 2. This indicates benefits for the non-primary roads of at least double those obtained for the primary roads, i.e. traffic is being guided away from non-primary roads.

The effect on traffic speed is shown in Table 3, and indicates an increase in average speed on the Non-primary roads.

The indications are that the Primary road network receives less benefit in terms of reduced vehicle kilometres and increased average speed, than the Non-primary network.

### TABLE 2

<table>
<thead>
<tr>
<th>Percentage of Guidance Users</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary roads</td>
<td>-0.2</td>
<td>-0.3</td>
<td>-0.5</td>
<td>-0.9</td>
</tr>
<tr>
<td>Non-primary roads</td>
<td>-0.4</td>
<td>-0.8</td>
<td>-1.2</td>
<td>-2.0</td>
</tr>
<tr>
<td>Total</td>
<td>-0.2</td>
<td>-0.4</td>
<td>-0.7</td>
<td>-1.3</td>
</tr>
</tbody>
</table>

### TABLE 3

<table>
<thead>
<tr>
<th>Percentage of Guidance Users</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary roads</td>
<td>1.7</td>
<td>2.0</td>
<td>0.7</td>
<td>-1.4</td>
</tr>
<tr>
<td>Non-primary</td>
<td>3.6</td>
<td>4.6</td>
<td>10.1</td>
<td>20.2</td>
</tr>
<tr>
<td>Total</td>
<td>2.4</td>
<td>2.9</td>
<td>3.9</td>
<td>5.3</td>
</tr>
</tbody>
</table>
3.3 RESTRICTING GUIDED TRAFFIC TO MOTORWAY AND A-CLASS ROADS

This test considered the effect of restricting guided traffic to a primary network comprised of motorway and A-class roads. The primary network chosen represented approximately one half of the LTS network, but carries approximately 70% of the total LTS vehicle kilometres driven.

The results shown in Table 4, indicate that restricting guided traffic to a primary network gives disbenefits in terms of network performance. There is a small increase in vehicle kilometres travelled, as guided traffic have to reach and leave the primary network. There is however a substantial increase in the time spent on the network which out-weighs any advantage arising from efficiency of routeing once guided traffic is on the primary network.

<table>
<thead>
<tr>
<th>% Guidance</th>
<th>Vehicle Kilometres</th>
<th>Vehicle Hours</th>
<th>Vehicle Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>0.6%</td>
<td>0.8%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>20%</td>
<td>1.5%</td>
<td>7.0%</td>
<td>-5.2%</td>
</tr>
<tr>
<td>30%</td>
<td>2.6%</td>
<td>15.8%</td>
<td>-11.4%</td>
</tr>
</tbody>
</table>

Restricting guided traffic to the primary network has disbenefits for both guided and unguided traffic. Although unguided traffic is unrestricted and able to use the whole network, it is adversely affected by the congestion created by guided traffic on the primary network. Figure 4, shows the percentage changes in journey time for guided and unguided traffic as the level of guided traffic is increased. At the 30% level of guidance there is a substantial increase in the journey time of the guided traffic (36%), and a smaller yet significant increase (7.5%) for the unguided traffic.

The results show that restricting dynamic route guidance to the primary network would introduce substantial traffic disbenefits for both guided and unguided traffic and would be an unsuitable strategy for a practical route guidance system.

3.4 THE DENSITY OF ROADSIDE COMMUNICATION BEACONS

Roadside beacons provide dynamic route guidance to equipped vehicles. The beacon equipment consists of a controller connected to a number of roadside beacons. Controllers are linked to a control centre and receive up-to-the-minute information on current traffic conditions (Belcher and Catling, 1987).

The objective of the study was to estimate the possible effects on the operation and benefit of route guidance for different densities of roadside beacons. Initially, road junctions were ranked according to traffic throughput, and the top 500, 1000 and 1500 junctions considered as beacon locations. This however, produced an over concentration of beacons in the M4 corridor and central area while other areas had insufficient beacons. To resolve this problem, junctions were selected on traffic throughput, but using a minimum distance apart criteria. Four minimum distance values were used; 0.5, 1.0, 1.5, and 2 Kilometres. The minimum distance value was increased from 0.5Km at the central area, to 2.0Km at the outermost traffic area. This ranking process gave a total of 555 junctions suitable for beacon location.

These sites provided guided vehicles with an average of three encounters, one every six minutes, for an average journey. A repeat ranking, with the minimum distances apart for beacons reduced by a half, gave a total of 1274 junctions suitable for beacon location. These sites provided guided vehicles with an average of 5.6 encounters, one every four minutes for an average journey.

The results suggest that approximately a 100% increase in the number of beacons is required in order to achieve a similar increase in the frequency of beacon encounters per trip.

4. THE SECOND STUDY

4.1 RESTRICTED NETWORK

The first study concerned the impact of dynamic route guidance with guided traffic restricted to Motorway and A-class roads. The results indicated guided traffic time and distance benefits would be drastically reduced. This second study considered the effect of restricting guided traffic to Motorway, A-class and B-class roads.
The traffic model assigns guided traffic to routes which minimise journey time. To restrict guided traffic to three road classes a time penalty was applied to the unclassified (U) road links. After assignment, road link costs were calculated less this time penalty, to derive total network vehicle hours and vehicle kilometres travelled. The number of links in each road class are shown in Table 5.

Table 5

<table>
<thead>
<tr>
<th>Road class</th>
<th>Links</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8744</td>
<td>52.1</td>
</tr>
<tr>
<td>B</td>
<td>2544</td>
<td>15.2</td>
</tr>
<tr>
<td>M</td>
<td>514</td>
<td>3.1</td>
</tr>
<tr>
<td>U</td>
<td>4972</td>
<td>29.6</td>
</tr>
</tbody>
</table>

Tests were made with guided traffic restricted to the three road classes and with no restriction to route assignment. The results allowed a comparison of three possible scenarios for the guided traffic; all roads available, restricted to motorway, A and B-class roads, and restricted to motorway and A-class roads. The results were presented as the percentage change from the network operated with no guided traffic and without route restriction.

The effect of 20% guided traffic on the network is shown in figure 5. With the whole road network available to guided traffic time savings of 3.3% were achieved.

Restricting guided traffic to motorway, A and B-class roads, increased network time by 2.4%. This increased to 7% when guided traffic was restricted to motorways and B-class roads. The comparable changes to the vehicle kilometres travelled are, -0.4%, 0.5%, and 1.5%. With the whole network available to guided traffic, speed increased by +2.9%. The restricted networks gave speed changes of -1.8%, and -5.2% when B-class roads were excluded.

The results for 100% guided traffic on the network were significantly worse. Guided traffic experienced a +68.4% increase in journey time when restricted to Motorway, A and B-class roads compared to -6.2% for the network without route restriction.

Restricting guided traffic to motorway, A and B-class roads excluded guided traffic from approximately 30% of the road network. The results demonstrate that such network restrictions will not produce time, distance or speed benefits for guided traffic. The benefit increases with the increased access to the road network and implies that route restrictions should be minimal to benefit guided traffic.

4.2 ACCIDENT COSTS

Two estimates were made of accident cost savings attributable to the introduction of a dynamic route guidance system.

(i) An estimate of accident costs using accident rates by road link type, and vehicle kilometres driven.

(ii) An estimate of accident costs using junction based accident rates (LRC,1987), which are a function of vehicle in-flow to a junction.

For both estimates the proportion of guided to unguided vehicles was 0%, 10%, 20%, 30% and 100%.

Link based estimates:

The accident cost savings attributable to route guidance were estimated from road link accident rates, and the vehicle kilometres travelled. Four types of road links were considered; motorway, one-way, dual-carriageway, and single carriageway. Estimating accident costs by road link type and vehicle kilometres does not consider the types of junctions, with different accident rates, through which traffic travels. However, the link based method provides an indication of accident costs.

The predicted cost of accidents is shown by Table 6. Accident cost savings could range from £2.3 million per annum (0.3%) with 10% guided traffic, to £11.9 million per annum (1.4%) with all traffic guided.

Junction based estimate:

The accident cost savings attributable to route guidance were estimated using road junction accident rates which are a function of the vehicle inflow to a junction. A total of nine different types of road junctions with associated
The predicted accident cost (£Million) by accident severity using a link based estimate.

<table>
<thead>
<tr>
<th>Accident Severity</th>
<th>Percentage of Vehicles with Route Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Damage</td>
<td>239.1</td>
</tr>
<tr>
<td>Slight</td>
<td>71.0</td>
</tr>
<tr>
<td>Serious</td>
<td>179.1</td>
</tr>
<tr>
<td>Fatal</td>
<td>335.4</td>
</tr>
<tr>
<td>Total (£M)</td>
<td>824.6</td>
</tr>
</tbody>
</table>

The costs are for a 24 Hour Annual estimate.

The predicted cost of accidents arising from the junction based estimate is shown in Table 7. Accident cost savings could range from 0.4% per annum with 10% guided traffic to 1.8% per annum with all traffic guided.

### 4.3 INTER-PEAK TESTS

The first study assessed the benefits of route guidance in the morning peak (0700 to 1000 hours). This study assessed the benefits of Autoguide in the inter-peak (1000 to 1600 hours), for cars and light goods vehicles at 0%, 20%, and 100% levels of guidance.

The inter-peak matrix was 2.9% smaller than the morning peak matrix. Although this is a small difference, the patterns of travel in the inter-peak gave shorter trip lengths and travel patterns that were more dispersed than for the morning peak resulting in less congestion.

### TABLE 7

The predicted accident cost (£Million) by accident severity using a junction based estimate.

<table>
<thead>
<tr>
<th>Accident Severity</th>
<th>Percentage of Vehicles with Route Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Damage</td>
<td>35.39</td>
</tr>
<tr>
<td>Slight</td>
<td>8.93</td>
</tr>
<tr>
<td>Serious</td>
<td>20.00</td>
</tr>
<tr>
<td>Fatal</td>
<td>36.66</td>
</tr>
<tr>
<td>Total (£M)</td>
<td>100.98</td>
</tr>
</tbody>
</table>

The use of route guidance in the inter-peak reduced the distance travelled, the journey time and increased the average speed. The results shown in figure 6, indicate the percentage improvements for 20% and 100% guidance over the network operated with no guided traffic. At the 20% level of guidance, distance travelled reduced by 0.2%, journey time by 0.82%, and average speed increased by 0.6%. At the 100% level of guidance, distance travelled reduced by 0.6%, journey time by 1.5%. and average speed increased by 0.9%.

The percentage improvement in distance travelled and journey time in the inter-peak period are approximately one quarter of that achieved for the morning peak period. Traffic in the morning peak is likely to be concentrated on routes leading to work related destinations. A greater spread of traffic between origins and destinations in the inter-peak means links are likely to be less congested. The savings gained from reducing the flow on a congested link are greater than for an equivalent reduction on a less congested link. This is likely to be the reason why smaller benefits result from the inter-peak assignment compared with the morning peak assignment.

The costs are for the Annual AM Peak period.
It could also be argued that the assignment method may contribute to reduced benefits in the inter-peak. The assignment method gives guided traffic perfect knowledge of link travel times and optimal routes. The unguided traffic take the sub-optimal routes, as they are assumed to know routes to their destination but lack the dynamic information available to the guided traffic. It is possible that in the inter-peak period the route knowledge is less than for the morning peak's regular commuter traffic. If this is the case then the use of route guidance would improve the benefits of inter-peak travel in excess of the benefits indicated.

**4.4 INCREASED TRAFFIC DEMAND (20%)**

This test considered the effect of an increase of 20% traffic demand on the network, for 0%, 20%, and 100% levels of vehicle guidance.

The use of route guidance with increased traffic demand (20%) on the network reduced distance travelled, journey time, and increased vehicle average speed. The results shown in figure 7, indicate improvements for 20% and 100% levels of guidance compared to the network operated with no guided traffic. At the 20% level of guidance, distance travelled reduced by 0.7%, journey time by 4.2% and average speed increased by 1%. At the 100% level of guidance, distance travelled reduced by 1.5%, journey time by 9.8%, and average speed increased by 9.2%.

Table 8, shows the percentage reduction in vehicle kilometres travelled and the journey time for 20% and 100% guided traffic compared to the network operated with no guided traffic. Three levels of traffic demand on the network were considered; the inter-peak (low demand), the morning peak (medium demand), and 20% increased traffic demand (high demand). The results indicate that over this range of traffic demand on the network, journey time and distance decreases with increased demand.

The results indicate that vehicle guidance will produce even greater benefits under higher levels of traffic demand expected in London in the future. This was the

<table>
<thead>
<tr>
<th>TABLE 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage changes in total time and distance with 20% and 100% guidance compared with no guided traffic.</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Proportion Guided</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Inter-Peak(low)</td>
</tr>
<tr>
<td>Morning peak(med)</td>
</tr>
<tr>
<td>Increased demand(high)</td>
</tr>
</tbody>
</table>

The Inter-peak and Morning peak were each simulated by a separate traffic demand matrix. The Increased Demand was simulated by factorising the Morning Peak matrix by 1.2.
case with an increase in traffic demand of 20%. There must however be an upper limit at which this relationship will cease to exist. At this point there will be insufficient capacity on the network to effectively re-route traffic. This study did not investigate the affects of traffic demands exceeding the 20% level.

5. CONCLUSION

The two studies were made to provide an estimate of the likely traffic impact of introducing a dynamic route guidance system to the London road network. The results of the studies are based on the use of the London Transportation Studies traffic assignment model. The results presented are illustrative, indicating the possible direction and scale of the effects and the following qualifications should be considered when assessing the results:

- All results are based on the average AM peak hour and it may not be possible to extrapolate the results to the off-peak period. A specific test for the inter-peak period was made in the second study.

- Goods vehicles are not considered.

- No second order effects of route guidance are represented such as the re-routeing of unguided traffic.

- Localised effects, such as routeing to a precise destination on local roads (terminal guidance) are not represented.

- Except were specifically indicated the main tests assume no network restriction on route choice.

- The effect of guided traffic was simulated using a trip matrix randomising technique.

The general indication of the two studies is:

1. Route guidance offers benefits to both guided and unguided traffic when operated on the London network with no route restrictions to guided traffic. Time saving benefits of between 6.3% and 6.9% were estimated for guided traffic and between 2.2% and 3.1% for unguided traffic, depending on the proportion (10% to 30%) of guided traffic using the London road network.

2. Route guidance benefits to the network in the inter-peak period (1000 to 1600 hours). The benefits in vehicle kilometres, time, and speed are approximately a quarter of benefits obtained for the morning peak period.

3. Route guidance operated with an increased traffic demand (20%), gave benefits in vehicle kilometres and vehicle time which were greater than obtained for the current morning peak period.

4. The effects of route guidance are not uniformly spread across the different London regions. The greatest benefits in terms of vehicle kilometres and vehicle speed are estimated for Inner London, with reduced benefits for Outer London.

5. Restricting guided traffic to a primary network of motorway and A-class roads, excluded guided traffic from approximately half the network, and introduced substantial disbenefits for guided and unguided traffic.

6. Restricting guided traffic to a primary network of motorway, A and B-class roads excluded guided traffic from approximately one third of the network. Although route restrictions were less severe, with access permitted to B-class roads, the results still indicate disbenefits for guided and unguided traffic.

7. The density of roadside communication beacons was investigated in relation to their spatial dispersion and the total number of encounters by guided traffic. For the two beacon densities considered, approximately 3 to 6 beacon encounters were estimated for an average journey.

8. There were small but significant accident cost savings attributable to the introduction of route guidance. The estimated cost savings could range from £2.3 million per annum (0.3%) with ten percent guided traffic, to £11.9 million per annum (1.4%) with all traffic guided.

6. ACKNOWLEDGEMENTS

The work described in this paper was part of the research programme of Traffic Operations Division (Division head: Dr W Gillan), of the Traffic Group, TRL. The TRL project officer for the first study was Mr J C Smith.

7. REFERENCES


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TRRL (1989(d)). Patterns of Vehicle Use in the London Area. CR131 Transport and Road Research Laboratory 1999.


MORE INFORMATION FROM TRL

TRL has published the following other reports on this area of research:
1. CR128 Study to show the benefits of Autoguide in London, JMP Consultants Ltd, Code F
2. CR129 Estimates of Autoguide traffic effects in London, MVA Consultancy, Code E
3. CR130 Recommended methodology for evaluation of route guidance in London and the potential for comparability with Berlin, Institute for Transport Studies, University of Leeds, Code F
4. CR131 A study to show patterns of vehicle use in the London area, Wootton and Jeffreys Consultants, Code F

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TRL facilities include a 2.3 mile test track, large structures test halls for static and fatigue testing, a dynamic pavement test facility, advanced computer systems and a large specialist library with on-line access to worldwide information.

If you are planning a project where we may be able to help, contact TRL (TTU) at Crowthorne, Berkshire RG11 6AU, telephone 0344 770004, fax 0344 770356.