THE GLASGOW EXPERIMENT:
PLIDENT AND AFTER

by

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ABSTRACT

The Road Research Laboratory has been carrying out a full-scale experiment in Glasgow to assess the benefits of various systems of co-ordinating traffic signals. Five different control schemes have been tested since the system became operative in November 1967. The fifth system, called PLIDENT, did not incorporate any formal linking. Platoons of traffic on main roads were identified and their arrival times at downstream signals were predicted. Green times were adjusted to suit the length of platoons, up to possible 3-min. maximums. Substantial improvements in journey times were obtained when the Combination method and TRANSYT were compared with the system of linked and isolated vehicle-actuated signals which existed in Glasgow in 1967. Neither FLEXIPROG nor EQUISAT appeared to give a measurable improvement over the basic fixed-time linked system, PLIDENT, the most elaborate and flexible of the systems tested, produced the longest average journey times recorded in the experiment. Details of the operation of PLIDENT are given, with a discussion of future work and policies for implementing area traffic control.

This report was prepared for the Joint Transportation engineering Conference, Chicago, October, 1970.

1. INTRODUCTION

The main purpose of the full-scale experiment on area traffic control carried out in Glasgow has been to find out whether central co-ordination of traffic signals is worthwhile and, if so, which systems of control produced the greatest benefits. The system, which includes 80 traffic signals in about 3 sq km of the city centre, became operative in November 1967. The control equipment, enabling all the signals to be co-ordinated on-line by a Marconi Myriad I digital computer, has been described in detail by Hillier (1). A simplified diagram of the road network controlled by the signals is shown in Fig.1.

Five different systems of control were tested during the period October 1967 to November 1969. The results of four of these trials have been reported elsewhere (2), but for completeness, they are included here.

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2. ASSESSMENT

A control system is assessed by comparing its performance with a "standard" system. Traffic measurements are made during weekdays for two weeks with the standard control system and for two weeks with the other system. Information on journey times and stopped times at junctions is obtained from four instrumented
cars which travel along a standard pattern of routes four times a day for the two-week period. Traffic counts were made manually during earlier surveys, but more recently they have been obtained by the computer from the pneumatic detectors on the approaches to the signals.

The main criterion used to assess a system is the total journey time spent per hour by vehicles in the network (3). For each 2-hr period, this value is plotted against the corresponding distance travelled by the vehicles to give the relation between the time spent and the distance travelled on the network. Over the two-week period of each assessment, this enables a journey time/flow graph to be plotted. The time required for a given amount of travel on the network using the standard control scheme is then compared with the time required for the same amount of travel under the control scheme.

3. PEDESTRIANS

The needs of pedestrians have been taken into consideration in all the signal control systems, about one-third of the signalized sections in the area having special pedestrian stages. The flexibility of the computer was used to give extra pedestrian stages at peak hours.

Accident records were also studied.

4. FIXED-TIME PROGRESSIONS, COMBINATION METHOD (STANDARD CONTROL SCHEME)

The first trial compared the standard control scheme with the local control system existing in Glasgow in the Autumn of 1967, which was a mixture of isolated and linked vehicle-actuated signals. The standard scheme consisted of three fixed-time plans for the morning peak, off-peak and evening peak conditions respectively, prepared from traffic observations made beforehand. The appropriate plan was selected for use according to the time of day. The co-ordination between signals was calculated by the Combination method (4), which is a systematic process of producing offsets which approximately minimizes the total delay on the network.

The results of the comparisons for the three periods are shown in Fig.2. Overall it was concluded that the Combination method settings produced a statistically significant improvement of 12 per cent in the average journey times of vehicles in Glasgow during the period covered by the survey.

5. FIXED-TIME PROGRESSIONS – TRANSYT

The second comparison in the Spring of 1968 was between the Combination method system and TRANSYT (5), an alternative method of obtaining fixed-time settings. Separate plans for each of the three periods of the day were also used in the TRANSYT tests. The traffic model used in TRANSYT is more realistic than the one used in the Combination method and includes allowance for the flow interaction between successive sections of roads and platoon dispersion. The mathematical optimization processes uses a hill-climbing technique to minimize the performance index which, in this case, was simply the total vehicle-hours per hour on the network.

Results of the comparison are shown in Fig.3. Overall it was concluded that TRANSYT produced a further improvement of 4 per cent in average journey times over the Combination method. An improvement of about 4 per cent had been predicted in the TRANSYT simulation before the trial.
6. VEHICLE-ACTUATED FLEXIBLE PROGRESSIVE SYSTEM — FLEXIPROG

The third trial tested a flexible progressive system (6) similar to the normal linked system used in Great Britain today and requiring the use of detectors on all approach arms. In principle, the signals change after detecting a suitable gap in the traffic which is running. The three fixed-time plans with the signal settings chosen by the Combination method were used to give the basic linking. The vehicle-actuated period within each cycle was as long as possible at each intersection.

The assessment of FLEXIPROG was carried out in the Autumn of 1968. The results, given in Fig. 4, showed that the scheme was not measurably better than the Combination method fixed-time scheme.

7. EQUAL DEGREE OF SATURATION SYSTEM — EQUISAT

The scheme used in the fourth comparison had the same cycle times and linking as the standard scheme. The allocation of green time within the fixed cycles could be varied automatically to equalize the measured degree of saturation on each stage. Detectors on each approach arm, and computer logic, were used to measure or deduce both flow and saturation flow.

The assessment of EQUISAT was carried out in the Spring of 1969. The program was seen to be making substantial and correct changes in green times in response to carrying traffic demands, but the observations showed that the scheme was not measurably better than the Combination method fixed-time scheme, Fig. 5.

8. COMMENTS ON FLEXIPROG AND EQUISAT

These results were rather surprising, as it seemed likely that a method which allocated green time to suit local traffic conditions should also improve network conditions and give lower journey times than the linked fixed-time system on which it was based. This still may be true for FLEXIPROG in very low flow conditions, for example at night, but these are conditions which the assessments did not cover. In moderately busy conditions, the green for a particular phase at a signal might start earlier with vehicle actuation, but there is no guarantee that the traffic thus released would be any better off when it has reached the next signal down the street.

In very busy conditions, signals operating in a gap-seeking flexible progressive system would be expected to revert to fixed-time working anyway.

It can also be argued that any overall improvements from EQUISAT might be small because:

1. The three Combination method plans had already been carefully selected to suit the average conditions for the periods being studied.

2. Lightly trafficked intersections are unlikely to benefit from redistribution of green times. It is thought that about three-quarters of the signals in the centre of Glasgow were sufficiently undersaturated for EQUISAT to make no appreciable difference to the delays at them.

Further investigations, largely based on simulation studies, are being carried out to establish whether small but useful benefits, undetectable by field studies, can be obtained from local optimization.
The idea of this control scheme was put forward by David Solomon of the United States Bureau of Public Roads during his secondment to the Laboratory. The scheme identifies the movement of platoons of traffic across the road network and aims to operate the signals in a way which avoids delay to platoons on certain priority streets. Only one approach to each signal may be a priority street, and priorities are, therefore, selected to handle as much traffic as possible. In Glasgow, where there are a number of one-way streets, about 40 per cent of the traffic travelled on priority streets.

The scheme has no fixed cycle or offsets, but adjusts the length of each stage to suit the various platoons. The scheme is thus radically different from any of those tried previously in Glasgow or, indeed, anywhere else in the world.

Platoons approaching each junction are defined by the expected time of arrival of the front of the platoon at the stop-line and by the expected number of vehicles in the platoon. The time of arrival is derived from:

1. The actual or expected time of start of green at the junction upstream.
2. A fixed time for the uninterrupted journey between the junctions.

The number in the platoon is obtained by multiplying the actual or expected number of vehicles entering the upstream junction by a factor which allows for the vehicles that turn out of the stream.

PLIDENT controls the signals, so that each stage normally continues at least until the end of saturation flow has been detected on all arms controlled by the stage (subject to a 180-sec maximum). The "end of saturation" signal for an arm is generated when the axle count over the last 8 sec is less than a certain specified figure; the count is obtained from a detector on the approach at about 30 m from the stop line. The specified figure depends on the estimated saturation flow, the time since the start of the green, and the proportion of the platoon that is estimated to have passed the detector as shown in Table 1. The estimated saturation flow is obtained from an exponentially weighted average using the 8-sec counts from 12 to 20 sec after the start of each green. If it is estimated that more than 0.8 of the platoon has crossed the detector before 20 sec after the start of green, a preset figure is used in place of the 8-sec count.

When end of saturation has been detected on all arms of the stage, a change to the next stage in order commences immediately, providing the minimum green has expired and the next stage does not show green to the priority street. If the next green does serve the priority street, the change is delayed by an amount sufficient to ensure that the next platoon arrives at the stop line immediately after the lights have changed and any waiting vehicles have cleared. The effect of this is to avoid delay to the platoon and, at the same time, to allow the waiting vehicles to be added at the front to form a single platoon for the next junction downstream.

<table>
<thead>
<tr>
<th>Proportion of platoon that has passed</th>
<th>Flow which will hold the green (expressed as a proportion of the saturation flow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 0.7</td>
<td>Green less than 20 sec 0.3</td>
</tr>
<tr>
<td>0.7 to 0.8</td>
<td>0.375</td>
</tr>
<tr>
<td>Greater than 0.8</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Some further features are also included in the scheme. The stage preceding the priority stage may be terminated without reaching "end of platoon" if this is necessary to avoid delay to the priority platoon, providing the non-priority stage is estimated to require less than 15 sec further green and that it ran to "end of saturation" on the previous occasion. If the non-priority green cannot be cut, the priority platoon is given its green as soon as possible up to a maximum of 10 sec late. If the platoon is delayed by more than 10 sec, it loses its priority and is added to the waiting vehicles, which are then held until the next priority platoon approaches. If "end of platoon" occurs on the stage preceding the priority stage, an immediate change to the priority stage is made without waiting for the next platoon if the data show that there is sufficient time to clear the waiting vehicles on the priority stage and service the other stages before a green is required for the next priority platoon.

The effect of PLIDENT is to give the priority streets just the amount of green they require at times which avoid delay to the approaching platoons. The non-priority streets are compensated to some extent for the lack of co-ordination of their green times with their platoon arrivals by being given the spare green time.

The scheme was compared with the standard control scheme in Autumn 1969. The results obtained are given in Fig.6 and show that PLIDENT gave considerably more delay than the fixed-time scheme.

The results of the experiment have not yet been studied in full detail. However, some facts have emerged from the preliminary studies and from general observations and discussions of the system, and these are indicated in the following.

There is no doubt that the system was working in the correct manner as detailed in the foregoing. The time of arrival of each platoon was estimated fairly accurately, and due allowance was made for any vehicles already waiting at the stop line; the end of saturation flow could also be detected correctly. The poor performance of the system is thus thought to be due neither to bad implementation nor to inadequate traffic detection. The system was implemented in Glasgow using only the standard pneumatic detectors about 30 m form the stop line. Strategically placed loop detectors would probably have simplified the computer programming, but it is not obvious that they could have improved the operation of the system substantially. The system was extremely flexible, and, to accommodate the observed traffic, cycle times at an intersection varied from the minimum of about 45 sec to enforced maximums of about 5 min.

There appeared to be relatively less delay on the priority routes than on the non-priority routes, although the priority routes were still substantially worse under PLIDENT than with fixed-time settings. It is believed that, on the priority routes, the marshalling of traffic into platoons in itself caused some delay which was not entirely offset by the very impressive handling of the platoons once formed. The delays on non-priority routes were presumably largely attributable to lack of co-ordination.

10. ACCIDENTS

A study (7) was made of the accidents in the experimental area of Glasgow during the first 12 months period of computer control, when the signals were normally operated by the computer between 08.00 and 18.00 from Monday to Friday. There was no significant change, at the 5 per cent level, in the number of injury accidents on weekdays in the computer controlled area, relative to an immediately adjacent area used for comparison. The actual number of accidents fell by about 8 per cent; there was a small indication that accident increased in severity. There was a nearly significant decrease of 35 per cent in accidents at signal controlled junctions, coupled with a 12 per cent increase at uncontrolled junctions.
11. WEST LONDON AREA TRAFFIC CONTROL

A complementary experiment on area traffic control by linked signals has been carried out in West London by the Traffic Control Division of the Ministry of Transport (8). The area covered by this experiment is about 15 sq km on the western approaches to London. Assessments in West London have generally confirmed the results obtained in Glasgow. Three fixed-time plans based on Combination method produced an average reduction of 9 per cent in journey time, and a further slight reduction was achieved using TRANSYT. A modified version of the flexible progressive system using Combination method linking produced no further improvement. Overall there has been a statistically significant reduction of 18 per cent in the number of accidents when compared with an adjacent control area.

12. DISCUSSION OF RESULTS

It has sometimes been suggested that the results obtained in Glasgow owe something to the particularly “grid-iron” nature of the street layout. This is not believed to have been a significant factor because steep hills in some parts of the city effectively prevent major through movements. Only part of the traffic network, as illustrated in Fig.1, reflects any marked grid-iron pattern. Confirmation of the Glasgow results in West London, an area of very different character, and also in several smaller studies, suggests that they may be generally applicable. It is hoped that TRANSYT in particular will be tried in America, Southern Asia, and Europe in the near future to establish its more general applicability.

It should be emphasized here that optimized fixed-time plans derived from off-line calculations were responsible for the major improvements. These optimized fixed-time plans did not appear to benefit from the addition of local vehicle-actuation, but it seems likely that less efficiently designed fixed-time plans might be improved by local vehicle-actuation.

The results referred to in this Report apply to working days between the beginning of the morning peak and the end of the evening peak. Further work is being planned to establish whether optimized fixed-time systems offer similar advantages at lower flows.

13. FUTURE WORK

A major part of the Laboratory’s future work in area traffic control will be the study of the best ways of implementing schemes based on “fixed-time” plans, but in no way does this preclude the possibility that other workers or future inspiration may show traffic responsive schemes to be superior.

The three main steps in the efficient use of fixed-time techniques are:

1. Predicting what the pattern of flows will be in the immediate future. This is necessary because calculation and subsequent plan changing take a finite time, the plan itself must suit traffic for some minimum period to merit its implementation at all, and it should be appropriate to traffic which is coming rather than that which has passed. There are several systems at present which use information from detectors for this purpose; others rely on “time of day”:
2. The production of plans to put in the "library". These have been based on the expected types of pattern likely to be encountered, but it is not easy to decide the number of plans required or the flow pattern for which each should be designed. In the light of the Glasgow results, an optimizing technique such as Combination method or TRANSYT should be used.

3. The selection of plans from the "library". Here the problem is to match the predicted flows with the available plans; a possible solution is to use a simple simulation (such as is used in TRANSYT) to estimate the total delay produced by each plan. This process, the equivalent of buying a suit "off the peg" should permit the selection of the best plan from those available. A further problem is to decide how frequently changes need to be made.

As an alternative to (1) and (2), the traffic equivalent of a "made to measure" suit is to calculate a suitable plan directly from the predicted flow. Modified versions of the optimization techniques already tested would be suitable for this task. The GEC/Elliott system in Madrid, described by Feuhrer (9), features a simple strategy of this type.

The key to all these systems is a satisfactory method of predicting what the flows will be in the immediate future. Research on this topic is now being done in Glasgow.

14. SIMULATION

A model capable of simulating a road network controlled by traffic responsive signals has been developed with the hope that it will lead to a more detailed understanding of the causes of some of the unexpected results observed in the Glasgow assessment. The simulation could also be used to help assess the value of applying to other town networks traffic control strategies evaluated in Glasgow. It will also be used to assess the value of small changes in control strategy which might be expected to produce small, but economically valuable, benefits.

The model has been described by Needham (10). Discrete vehicles are used and each is considered once in each simulated second. Present traffic control strategies only require knowledge of the passage of vehicles past certain key points in the network, e.g. detectors and stop lines; therefore, it was felt unnecessary to accurately locate particular vehicles except at these key points. The model transfers vehicles from detectors to stop line and from stop line to detector with journey-time and stopped-time delays between each. A special feature of the model is the ability to tag and direct certain vehicles through the network and to record their behaviour in detail. These will be used to verify the simulation by comparison with the floating cars used for assessment in Glasgow.

A simplified 80 intersection model with fixed-time control of the signals has been run on an ICL 4-70 computer at about four times faster than real time. A 20 intersection sub-area of Glasgow has been simulated in detail (at about 9 times faster than real time), and the first few comparisons of Combination method and TRANSYT are encouragingly similar to the results obtained during the actual surveys. There is, however, some distance to go before a model of a network the size of Glasgow can be used confidently to answer some of the detailed questions.
15. CONCLUSIONS

Substantial improvements in journey time have been produced in Glasgow and in West London by co-ordinating all the traffic signals in the area on a fixed-time basis. When the Combination method was used to select the signal settings, average reductions of journey time of 12 per cent in Glasgow and 9 per cent in London were achieved. In economic terms, these represent savings to the community of £500,000 and £2.25 million annually, respectively. (The capital outlays were £330,000 and £550,000, respectively, in both cases for a system with far more capability than that required for fixed-time working). Further savings were achieved when TRANSYT was used to select the signal timings.

No further advantage has been found by superimposing local optimization of each signal on to a basic, optimized fixed-time system. The vehicle-actuated flexible progressive system did not prove any better than the fixed-time system in either West London or Glasgow. In Glasgow, EQUISAT similarly showed no additional benefits.

The very flexible system PLIDENT, which does not incorporate any formal linking, but which identifies and handles platoons of traffic on the main routes, was successfully implemented but produced the largest average journey times recorded in the Glasgow Experiment.

The work described was primarily concerned with strategies for area traffic control, and the conclusions reached are independent of the method of their implementation in practice. Issues such as the proportion of a system achieved by hardware or software, the type of data transmission, the use of one or several computers, whether the computers are digital or analog, and whether some functions are better carried out at the roadside or in the computer centre, must be decided on the particular merits of each case.

16. POLICY

In view of the high return on investment already demonstrated, it has been decided in Great Britain that grant assistance for about three installations per year will be provided to local authorities to install area traffic control systems. The criteria provisionally adopted are that the number of signals in a system is not less than 30, and either the signal density is more than four intersections per square kilometre or the average number of signals along a route or routes is not less than 4 per km. It is estimated that these criteria are met in 15 to 20 cases in Great Britain at present. It is recommended that allowance should be made in the system design for possible expansion to take advantage of any further development of more flexible systems. The setting of existing linked signal systems to Combination method or TRANSYT timings will also be eligible for temporary grants over the next three years.

17. ACKNOWLEDGEMENTS

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18. REFERENCES


Fig. 2. COMPARISON OF EXISTING CONTROL AND COMBINATION METHOD SETTINGS
**Fig. 3. Comparison of TRANSYT and Combination Method**

- **Morning Peak**
  - Time spent in central area (vehicle-h/h)
  - Distance travelled in central area (vehicle-km/h)

- **Mid-Day**
  - Speed (km/h)
  - Not statistically significant

- **Evening Peak**
  - Combustion method

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**Time spent in central area (vehicle-h/h)**

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Distance (vehicle-km/h)</th>
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<tr>
<td>1000</td>
<td>20,000</td>
</tr>
<tr>
<td>2000</td>
<td>28,000</td>
</tr>
<tr>
<td>3000</td>
<td>30,000</td>
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<tr>
<td>Speed (km/h)</td>
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<tr>
<td>12</td>
<td>20,000</td>
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<tr>
<td>14</td>
<td>26,000</td>
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<td>16</td>
<td>30,000</td>
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<td>18</td>
<td>34,000</td>
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Fig. 4. COMPARISON OF VEHICLE-ACTUATED FLEXIBLE PROGRESSIVE SYSTEM AND COMBINATION METHOD
Fig. 5. COMPARISON OF EQUAL DEGREE OF SATURATION SYSTEM AND COMBINATION METHOD

* Excluding north-west corner
Fig. 6. COMPARISON BETWEEN PLIDENT AND COMBINATION METHOD

* Excluding north-west corner
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