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STRATEGIES FOR AREA TRAFFIC CONTROL SYSTEMS: PRESENT AND FUTURE

by

Joyce Holroyd and D I Robertson

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Traffic Management and Control Division
Traffic Engineering Unit
Transport and Road Research Laboratory
Crowthorne, Berkshire
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ABSTRACT

Different techniques for co-ordinating traffic signals in an area have been subjected to full-scale tests by the Transport and Road Research Laboratory. The characteristics of the techniques and results of the tests are summarised in this report. It is concluded that the case for using traffic-responsive systems is not proved because fixed-time plans based on historical data and calculated off-line by a technique such as TRANSYT, the COMBINATION METHOD or SIGOP, gave a performance at least as good as any other technique tested and would have been less expensive to install.

Possible future developments in traffic-responsive control strategies are reviewed.

First presented at the Second International Symposium on Area Traffic Control Systems held in Toulouse, France, 8–10 November 1972 under the auspices of the Organization for Economic Co-operation and Development.

1. INTRODUCTION

A number of different techniques for co-ordinating traffic signals in an area have been subjected to full scale tests by the Transport and Road Research Laboratory. The systems tested fall broadly into three types, namely:

1) Fixed-time plans based on historical data and calculated off-line by a computerised optimising technique.

2) Systems in which each signal can respond individually to traffic detected on the approach arms subject to some basic co-ordination as given in 1).

3) Fully responsive systems in which all the signal settings are calculated on-line using a control strategy and information from detectors.

To date systems in categories 1) and 2) have been the most successful, when assessed in terms of overall journey time of traffic in the network. It follows from this that taking into account installation costs, the optimised fixed-time systems 1) are the most satisfactory. This result is perhaps surprising as intuitively it would seem that vehicle-responsive area control systems should give less delay to traffic than fixed-time ones; this is certainly true for isolated intersections.

All the tests carried out by the Laboratory have been described elsewhere. In this paper summary tables are given together with some discussion of the performance of the various systems.

An indication of the way in which future systems may develop is also given.

2. DISCUSSION OF RESULTS

A brief description of the systems tested by the Laboratory is given in Table 1 and a summary of the results is given in Table 2. Various aspects of the results are discussed below.

2.1 Fixed-time systems

The general conclusion from the tests on Combination method, TRANSYT and SIGOP is that these fixed time systems are as effective as any yet tested and that TRANSYT has been shown to give the shortest journey times of all. Some of the other aspects which arose from the tests are given below:

1. The tests with SIGOP and TRANSYT showed that 'double-cycle' TRANSYT (in which the less saturated signals run on half the cycle time used by the more heavily loaded signals) gave a 4 per cent improvement in journey time when compared with TRANSYT with a single cycle time throughout the network. In Glasgow about 50 per cent of the signals were on full cycle and the remainder on half that cycle.

2. The result of the test of TRANSYT against isolated vehicle actuation in very light flow conditions is particularly interesting. Under the very light flow conditions in the early morning when the total number of vehicles in the network averaged about 70, isolated vehicle actuation might be expected to be very efficient, as any moving vehicle should either arrive during a green stage or call the green immediately on being detected. The test showed that an optimised fixed-time system, with no detection of vehicles at all, could produce an equally efficient system in terms of average journey time. The fixed-time system could almost certainly have been improved further by eliminating some of the pedestrian stages, which, at that time of night, were largely superfluous. The isolated vehicle-actuated system might have been improved by the use of reversion to main road green; however the benefit from doing this would be expected to be small.

2.2 Vehicle-actuated flexible progressive system, FLEXIPROG

The reasons why this system has failed to show any measurable improvement over fixed-time have not been investigated in detail. However, some comments are given below:

1. In very busy conditions the FLEXIPROG system would revert to fixed-time settings.

TABLE 1

Description of systems tested

	References
1. *Fixed-time plans based on historical data and calculated offline by a computerised optimising technique*	
All three techniques are essentially aimed at calculating the offsets of traffic signals in an area so as to minimise a performance index. The performance index can be any chosen combination of stops and delays; delays only were used in Glasgow.	
1.1 *Combination method* assumes that all the signals have a known single cycle or a cycle which is a sub-multiple of some master cycle. The green splits are also assumed known. The method takes account of the volume of turning traffic. The delay to traffic in one direction along the section of road between two signals is however assumed to depend only on the difference of the settings of these two signals and not on any other adjacent signal. A dynamic programming optimisation principle is used to find a true global optimum subject to some constraints on network configuration.	(1)
1.2 *TRANSYT* assumes that all the signals have a known single cycle or a cycle which is a submultiple of some master cycle. The method uses a simple but effective model of the traffic which includes allowance for turning traffic, platoon dispersion and the flow interaction between successive sections of road. The optimisation process uses a hill-climbing technique to minimise the performance index. Splits can be optimised as part of this process.	(2)
1.3 *SIGOP* uses a somewhat simpler model than the Combination method. Offsets are calculated by a hill-climbing technique. SIGOP calculates splits independently of the offset optimisation. Signals are assumed to all work on the same cycle but several cycle times are evaluated in one computer run. Delay predictions are made for the final settings by using a simple simulation.	(3)
2. *Co-ordinated systems with local traffic response at each signal*	
Both techniques used Combination method or TRANSYT for the underlying co-ordination and information from pneumatic detectors for local adaptation.	
2.1 *FLEXIPROG* With a continuous stream of traffic over all detectors, the signals change according to the underlying fixed-time system. In lighter traffic the signals can change after detecting a suitable gap in the traffic. Stages are missed out if there is no demand for them.	(4)
2.2 *EQUISAT* In this system cycle times and order of the stages are fixed; the offset of the middle of one green is fixed by the underlying fixed-time system. The allocation of green time is varied to equalize a smoothed average of the degree of saturation on each stage.	(5)
3. *Fully responsive systems*	
In both these systems, all the signal settings are calculated on-line using information from detectors.	
3.1 *Dynamic plan generation* Flow counts from detectors are used to calculate cycle times and splits according to the principles given by Webster and Cobbe. Offsets are calculated to minimise delay or stops using measured or estimated speeds and a simple model of traffic behaviour down the link. Cycle times, splits and offsets were recalculated every 3 cycles during the test.	(6)(7)(8)
3.2 *PLIDENT* This system has no formal cycle time or linking. The scheme identified the movement of platoons of traffic on the road network and, by predicting arrival times, aimed to operate the signals so as to pass the platoons unimpeded on the higher priority routes. Green times were adjusted to the correct length for each individual platoon.	(9)

TABLE 2

Summary of test results

System	Main tests	Main results	Other evidence	References
1. *Fixed-time*				
1.1 Combination method	Compared with the system existing in Glasgow in 1967 which was a vehicle-actuated system, linked on the major routes, with a single plan for the whole of the day. Three Combination plans were tried for morning peak, off-peak and evening peak.	Combination method gave consistently shorter journey times with all three plans (average 12 per cent).	Similar test in West London gave similar results (average 9 per cent, not significant).	(9)(10)(
1.2 TRANSYT	Compared with Combination method for three plans; morning peak, off-peak and evening peak (1968).	TRANSYT gave consistently shorter journey times with all three plans (average 4 per cent).	Similar test in West London gave similar results (average 2 per cent, not significant).	(9)(10)
1.3 SIGOP	1) Compared with TRANSYT for three plans; morning peak, off-peak and evening peak. TRANSYT used half cycle times where appropriate (1971)	1) No measurable difference in morning peak SIGOP gave longer journey times for other two plans (average 4 per cent).		(12)(10)
	2) As above with TRANSYT using full cycle times only, same cycle times as SIGOP (1971).	2) No measurable difference in journey time with any plan.	2) Similar test in San Jose gave similar results.	(12)(10)
2. *Locally adaptive systems*				
2.1 FLEXIPROG	1) System with Combination method for the basic linking compared with the same fixed-time Combination method settings for three plans; morning peak, off-peak and evening peak (1968).	1) No measurable difference in journey times with any plan.	1) Slightly different version of FLEXIPROG in West London gave a slight improvement (2 per cent) which was not statistically significant.	(9)(10)
	2) System with TRANSYT for the basic linking compared with the same fixed-time TRANSYT settings for an off-peak mid-day plan, but tested in the evening 1930 to 2130 (1971).	2) FLEXIPROG gave longer journey times (13 per cent).		(13)(10)
2.2 Isolated vehicle actuation	Compared with TRANSYT under very light flow conditions between 0100 and 0300 (1971).	No measurable difference in journey times with systems.		(9)(10)
2.3 EQUISAT	System with Combination method for the basic linking compared with the same fixed-time Combination method settings for three plans; morning peak, off peak and evening peak (1969).	No measurable difference in journey times with any plan.	Slightly different version of EQUISAT (containing a minor error in logic) tested earlier gave longer journey times (5 per cent) in the morning peak, no measurable difference with other plans.	(9)(10)
3. *Fully responsive systems*				
3.1 Dynamic plan generation	Compared with fixed-time system using hill climb technique similar to TRANSYT in Madrid in 1970. Three different fixed-time plans compared during four periods of the working day, including the peak periods.	Dynamic signal plan generation system gave consistently longer journey times (average 9 per cent).		(14)(10)
3.2 PLIDENT	Compared with Combination method in 1969. Three different Combination plans used for comparison during morning peak, off-peak and evening peak.	PLIDENT gave consistently longer journey times (average 29 per cent).		(9)(10)

2. In moderately busy conditions the green for a particular stage at a particular signal might start earlier with the vehicle actuation, but there is no guarantee that the traffic thus released will be better off when it reaches the next signal down the street.

3. The test made in moderately light conditions in the evening (between 1930 and 2130), showed that the vehicle-actuated system gave significantly longer journey times than the basic fixed-time system. In this test the basic linked plan was not optimised for the prevailing traffic conditions and subjective assessment of the fixed-time plan suggested that it was not ideal for the conditions in the evening. However, this mis-match may not have been important for the following reasons: (a) simulation studies have shown that a good optimised fixed-time plan performs fairly well under quite wide variations of traffic; (b) a 'better' plan could have been produced to suit the evening flows and incorporated in both the fixed-time system and the associated vehicle-actuated system, but the improvement, probably of only a few per cent in journey time, would have applied to both systems. The effect of superimposing vehicle actuation on a non-optimum plan is not really known, but it might be expected to produce more variation in the timings than if the plan were optimum. The relatively light flows in this test would also tend to produce more variations in the signal timings than in the daytime tests. Data available on signal changes throughout a typical two-hour test period showed that there were considerable variations in the timings and that the progressions on the main routes were frequently interrupted by the changes. This could explain the longer average journey times measured in the network. The FLEXIPROG system tested in West London permitted less variation in the green times than the system tested in Glasgow and this feature may account for differences in the results. Further research is probably required into the effect of the freedom permitted to green time variation within FLEXIPROG systems and the consequences on stability of signal operation.

4. In very light flows FLEXIPROG is effectively the same as an isolated vehicle-actuated system; the test on this has been discussed above.

2.3 EQUISAT

Reasons why EQUISAT showed no improvement over fixed-time are thought to include the following:

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

2. Undersaturated 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.

2.4 Dynamic signal plan generation

To improve on the optimised fixed-time system the dynamic plan generation system has to carry out all the following steps on line:

1. Predict the flow pattern in the immediate future

2. Calculate good optimized settings from the predictions

3. Change the signal timings to a new optimised plan with the minimum of disturbance.

The installation in Madrid incorporated all these three basic features, but as can be seen from the results further work is necessary. It is felt that improvements could be made to the dynamic system in Madrid by more accurate predictions of traffic volumes for more sections of road. It has been suggested by GEC-Elliott Traffic Automation Ltd that this might be achieved by doubling the number of detectors.

As a result of some additional features and improvements, the dynamic system in Madrid is believed to be more effective now than when the test was carried out. The system is less prone to the formation of the exit queues which caused problems during the assessment.

Research is being carried out by the Ayuntamiento de Madrid and also by GEC-Elliott Traffic Automation Ltd in association with the Transport and Road Research Laboratory. The work includes the prediction of flow, the sensitivity of optimised plans to variations in traffic pattern and the temporary disruption of traffic caused by the alterations to signal timings during a plan change. Work is also being carried out on the performance of a system under overload conditions.

2.5 PLIDENT

There is little doubt that the system was working as intended. 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 from 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 seconds to enforced maximums of about 5 minutes.

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.

3. WILL FUTURE TRAFFIC SYSTEMS BE RESPONSIVE?

A considerable number of different types of traffic-responsive control strategies have been proposed. Some have been tested by simulation but only a small number have been tested on street networks of appreciable size. A proportion of these street tests have involved careful measurement of traffic behaviour against a well defined control standard. The tests of EQUISAT, FLEXIPROG, PLIDENT and Dynamic Plan Generation fall into this category. As mentioned earlier in the paper, these tests did not show any measurable journey-time benefits to support the use of traffic-responsive control strategies.

In the absence of other strong evidence, the present conclusion of the authors is that the case for using traffic-responsive systems is not yet proved. Further evidence is likely to become available in the next two or three years from research projects which are underway in several countries.

The widespread use of traffic-responsive systems will depend on the magnitude of the system costs in relation to the traffic benefits. Both costs and benefits depend on the control strategy adopted and these aspects of traffic-responsive systems are discussed below.

3.1 Systems costs

The cost of a computer-controlled traffic system which implements a fixed-time plan control philosophy varies widely about a mean in the region of £¼ million for the central equipment and £2000 per signallised intersection.

The central equipment includes the computer with digital input/output control devices, backing storage, mimic displays, some manual control facilities and installation costs. The cost per intersection includes modifications to existing signal controllers, allowance for a proportion of new controllers and data transmission instation and outstation equipment. The cost per intersection does not include any provision for vehicle detectors since these are not essential to a fixed-time system. In practice, limited numbers of detectors are usually installed but in such numbers as to have little effect on total system cost.

It is apparent that a traffic-responsive system will be more expensive than a fixed-time system. One important reason is that the former will require information from vehicle detectors. Assuming inductive loop detectors are used, then each detector will increase system costs approximately as follows:

Item	£
– Detector unit	40
– Installation of 50 metres of loop and feeder cable by slotting	100
– A 50 baud VF modem pair	100
– Computer digital input	20
– Share of housing, connection and test	40
Total	300

This total assumes that no extra data transmission lines are required and that one voice-frequency data transmission channel is used for each detector. The costs of traffic signal control and monitoring are not likely to be significantly affected, provided that the computer already has the facilities to change signal aspects when required.

Central equipment costs may also increase because extra storage is likely to be required by the more complex traffic-responsive programs and the increased calculation load may mean that at least one extra computer is required to control a traffic network of a given size. Taking these factors into consideration, an example of the variation in system costs for a 100 intersection network is given in Table 3.

The number of detectors required will depend on the number of measuring sites at an intersection and the number of detectors at each site. Costs can be seen to rise appreciably depending largely on the number of detectors required, and it is unlikely that a traffic-responsive system will provide significant benefits unless there is an average of at least four detectors per intersection.

TABLE 3

System costs for fixed-time and traffic-responsive
control of 100 intersections

Control strategy	No. of detectors per intersection	Total cost
		£
Fixed-time	small	450,000
Traffic-responsive	1	530,000
	4	650,000
	10	900,000

3.2 Traffic benefits

Analysis of data on fixed-time systems shows that the average number of vehicles queuing at an intersection in an urban area varies from city to city, by time of day, day of week and so on but is usually in the range 5 to 20 vehicles. Below this level the traffic conflict is such as to rarely warrant signal control and above this level further demand is deterred by excessive queues.

Taking an average of 10 vehicles queueing through each working day and valuing one vehicle-hour of delay at £1, then, with some allowance for the delay outside working hours, the loss to the community from delay at one 'typical' urban intersection is about £40,000 per annum. If a traffic-responsive system achieves a 10 per cent delay reduction compared with an off-line optimised fixed-time plan then the annual benefit in the 100 intersection network would be £400,000. With this rate of return the extra cost of 10 detectors would be recovered in about one year. A 10 per cent reduction in delay seems to be a modest target and corresponds to a reduction in journey time approaching 5 per cent. The use of fixed-time plans in Glasgow secured journey-time benefits compared to the original system of up to 16 per cent during the working day; this corresponded to a first year rate of return of nearly 200 per cent on the original investment.

The journey-time benefits calculated above assumed that traffic demand would not change, but it is possible that an increased efficiency in use of the road network might encourage an increase in demand. In some networks it may be necessary to restrain demand by techniques such as parking control in order to maintain the community benefits resulting from better control systems.

Better systems may well bring other benefits; for example, delay reduction should reduce air and visual pollution. A suitable traffic-responsive system may also permit more efficient application of bus priority techniques to improve scheduled operation.

3.3 Deficiencies of fixed-time systems

Traffic-responsive systems can only be successful if there are significant deficiencies in fixed-time systems. Before considering these deficiencies, it is worth remembering two advantages of fixed-time systems:

1. The signal timings are predictable and vehicle drivers can learn to adapt their routes and speeds to their own best advantage. The importance of this effect is not known.

2. Fixed-time systems are simple in concept, implementation and operation.

At the same time they have the following deficiencies, the importance of which remains to be established:

a. The plan timings may be non-optimum because assumed average flow levels do not match the actual average flows. There may be many reasons for this mis-match including temporary variation in flow patterns due to an accident or road closure, the weather (rain, snow, ice) or simply that the plan timings have not been kept sufficiently up to date. Wrong decisions on plan change times (or flow levels) can also cause errors.

b. Even if the assumed average flows are correct, the fixed-time plan can take no account of the short-term fluctuations about the average.

c. Considerable effort must be expended on off-line plan calculation and there are practical limits to the number of plans which can be produced.

d. Fixed-time plans may not be appropriate for oversaturated conditions in which blocking back into upstream intersection becomes a problem.

4. FUTURE DEVELOPMENTS IN TRAFFIC-RESPONSIVE CONTROL STRATEGIES

A wide variety of traffic-responsive strategies have been proposed because the problem of network control is too difficult to solve without making a number of controversial and restrictive assumptions. To illustrate the problem, in a network of 100 intersections about 4 signal aspect changes are being made every second. Each change could be advanced or delayed with consequences on other changes. The combination of possible signal sequences is astronomically large, even over a 5 minute period.

4.1 Classification of strategies

It is convenient for discussion to sub-divide control systems into several groups. One of the most important characteristics is whether adjacent signallised intersections work on a common cycle time. If so, it can be said that the system belongs to the 'common cycle' class and, if not, to the 'free cycle' class.

A further useful subdivision can be made between systems which use an 'on-line model' of the traffic situation to assess the merits of alternative control policies and systems in which the signal control decisions have been predetermined off-line as a consequence of a 'fixed policy'.

Control strategies which fall into these classes are discussed below.

4.2 Free cycle

With this class of system, there is no requirement that adjacent intersections work on a common cycle. Common cycle operation may well occur between some or all intersections for short or long periods but it will be as a consequence of, rather than a precondition of, the strategy employed.

4.2.1 Free cycle with fixed policy PLIDENT is of this type and the Glasgow experience demonstrates the problems associated with removing the common cycle restriction.

Queue control strategies have been studied in which the fixed policy is based on terminating the green period when the queue on an approach has discharged. The policy becomes quite complicated in networks with multiple approaches to each intersection. There are difficulties with accurately estimating queue size but work reported by Wagner[15] and others suggests that further development and testing of this strategy is worthwhile.

4.2.2 Free cycle with on-line model The authors are not aware of any published results of comparative tests on systems of this type. The control problems appear to be formidable but the performance potential is probably the greatest.

Kay[16] has shown that the TRANSYT model can be modified so as to study transient traffic conditions during successive signal cycles rather than stable conditions over many cycles. In principle it appears to be possible to put this type of model on-line to give a short-term, detailed prediction of traffic behaviour over, say, the next 2 to 4 minutes. The prediction would be based on current detector data projected into the near future by the TRANSYT platoon dispersal and stopline queueing model. On-line decisions on signal timing must then be made using the model predictions to evaluate alternative policies. The TRANSYT and SIGOP methods both show that hillclimbing optimisation techniques work well in fixed-time signal networks but the application to time-varying situations may present special problems.

The computing load associated with strategies incorporating on-line modelling and free-cycle times is very heavy. One process control type of computer with sub-microsecond instruction times is unlikely to be able to control more than 50 to 100 intersections.

It is the authors' view that this type of strategy warrants further investigation.

4.3 Common cycle

When the common cycle principle is used, signalled intersections within a network are formed into one or more groups of adjacent intersections and each intersection within a group has the same basic cycle time. Small variations in cycle time may be permitted without upsetting the assumption.

A problem arises when making a choice of intersection grouping. An important benefit of grouping on a common cycle is that it is possible to arrange favourable progressions between adjacent intersections. A penalty is that all intersections except the critical one must be operated on a longer cycle time than their individual optimum and, in general, this will cause extra delay which may sometimes offset the benefits of progression. At the present time, choice of intersection grouping is largely a process involving judgement. TRRL plan to study the benefits and penalties associated with intersection grouping.

Once a choice of grouping has been made, and it may prove possible to put such decisions on-line, then within a group the remaining problems are concerned with making a good choice of cycle time, phase sequence, splits (distribution of green time) and offset between signals. These problems can be solved in various ways.

4.3.1 Common cycle with a fixed policy A considerable number of systems of this type have been proposed, tested and, in some cases, sold. The usual method is to fix cycle time and offsets using a fixed-time plan calculated off-line. The signal splits are then varied on-line in accordance with fixed policies based on detection of individual vehicles and/or calculations of spare green time available. FLEXIPROG and EQUISAT are of this type, and similar systems have been implemented in the USA (eg Wichita Falls and San Jose) and in Germany.

The additional journey-time benefits of this type of system, when compared with a fixed-time system, are likely to be small because split variation is probably only useful at critical junctions. In fact, no improvement could be measured with FLEXIPROG and EQUISAT in Glasgow.

Systems which use a background, precalculated fixed-time plan must have the plan changed at intervals throughout the day and, of course, off-line plan calculation is necessary. Further, large changes in cycle time cannot be made without recalculation of offsets.

4.3.2 Common cycle with an on-line model The Dynamic Plan Generation system tested in Madrid is an example of this type of system. A simple model was used to calculate offsets on the basis of measured traffic flows, cycle times and splits being calculated on-line with a fixed policy. Although the system tested in Madrid in 1970 gave longer journey times than the fixed-time method, there would appear to be considerable development potential in this type of approach. The computer calculation load, although higher than with fixed-time plans, is unlikely to be anything like as great as that required if a full on-line traffic model is employed.

The success of the off-line optimisation procedures would suggest putting a process of this type on-line, although it is by no means certain that significant journey-time benefit will result. One obvious approach would be to implement TRANSYT more or less as it is used off-line, except that the total flows along the network links would be predicted from detectors (see 5 below). Having obtained representative predicted flows for the period to be controlled, the model and optimiser could be used to improve the signal timings. Small changes in offset, split and cycle time could be implemented within seconds. Large changes of offset and possibly regrouping of signals on a common cycle could be made at intervals, probably not less than 15 minutes, in order to minimise the effect of transients. Such a technique would require storage and manipulation within the computer of flow patterns for each stopline. These patterns would need to be held with a resolution of about 32 elements for a maximum cycle time of 128 seconds.

To establish whether this method might be feasible, consider a network of 100 intersections, each of which has a stage change every 25 seconds. This would mean 4 stage changes per second on average. Prior to each stage change assume that the optimiser uses the on-line model to investigate a limited number of alterations to the timings at that intersection – say 5 such alterations. To evaluate each alteration it may be necessary to consider the effect on, say, 10 links upstream and downstream from the intersection. Each link must have the variation in inflow, queue, outflow, delay and stops calculated over one cycle. Assume that to give adequate resolution of traffic flow behaviour there are 32 steps in one cycle. Suppose that the calculations for each step require, on average, 50 machine instructions.

The average number of machine instructions per second

= 4 x 5 x 10 x 32 x 50

= 320,000 per second.

This would indicate that this procedure is just about practical if the latest and fastest type of digital process control computers are used.

With this type of system there are various options concerned with whether information (other than average flows) which is required by the traffic model is measured on-line or pre-set. For example journey time could be measured on-line. Much research work would be required to resolve such questions.

5. PREDICTION

Regardless of its type, to be effective any traffic-responsive strategy must handle the prediction problem satisfactorily.

The essence of the prediction problem is that data from detectors give information about past traffic. behaviour while the traffic-responsive system must take decisions which result in good control in the future. Ways must be devised to predict future traffic behaviour from past detector measurements. Some preliminary studies of the prediction problem have been made using data from detectors in Glasgow. It has been found that detectors can be used to give very short-term predictions (for a few seconds ahead) of demands further downstream. For medium-short periods ahead (a few seconds to several minutes) prediction of the fluctuations in traffic is very difficult because of the effect of the cycle time of the signals, turning traffic and interference from parked vehicles. No method of prediction for these intermediate periods was better than ± 30 per cent.

For periods of 10 to 20 minutes, flow in the next period can be predicted by averaging current flows. These predictions had a 95 per cent probability of being within ± 20 per cent of the measured flow in the next period. For even longer periods ahead, historical data from a previous similar day-of-the-week gave a better estimate. Predictions of hourly flows had a 95 per cent probability of being within ± 10 per cent when estimated from the similar week-day one week earlier.

For prediction periods in the medium-to-long range, it is to be expected that the best prediction would be made by a suitable combination of historical and current data. The accuracy of this technique is not known.

These preliminary figures should be treated with reserve, but they show the possible limitations of the data on which traffic-responsive schemes must operate.

6. STANDARD OF COMPARISON

A major success of recent international co-operation on traffic research is the acceptance by traffic engineers in many countries of the need to test any new signal control system against a widely-known and well-defined common standard of control. The published results of some early tests were not as useful as they might have been because there was no such common standard.

In the authors' opinion the most suitable common standards at the present time are TRANSYT and its American counterpart, SIGOP.

Apart from tests within the UK, TRANSYT has been compared with SIGOP in San Jose, USA, a Dynamic Plan Generation system in Madrid, Spain, and a French development of the method called THESE in Rouen. In addition working versions of TRANSYT or later developments of the method are used in Italy, Switzerland and the Netherlands.

7. CONCLUSION

The conclusion from the Glasgow tests on the Combination method, TRANSYT and SIGOP is that these fixed-time systems are as effective as any yet tested. Double-cycle TRANSYT gave the shortest journey times overall. This conclusion is supported by some evidence from other tests.

The case for using traffic-responsive systems is not yet proved on present evidence. There are several possible avenues which future developments could follow, and these are described in the paper.

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9. REFERENCES

1. HOLROYD JOYCE. The practical implementation of Combination method and TRANSYT programs. *Department of the Environment, TRRL Report* LR 518. Crowthorne, 1972 (Transport and Road Research Laboratory).

2. ROBERTSON D I. TRANSYT: A traffic network study tool. *Ministry of Transport, RRL Report* LR 253. Crowthorne, 1969 (Road Research Laboratory).

3. ANON. SIGOP traffic signal optimisation program users' manual. Peat, Marwick, Livingston & Co., New York, 1968.

4. ROAD RESEARCH LABORATORY. Research on road traffic. HMSO, London 1965, p 291.

5. HOLROYD JOYCE and J A HILLIER. Area traffic control in Glasgow: a summary of results from four control schemes. Traff. Engng & Control, 1969, *11* (5), 220–3.

6. VALDES A and S DE LA RICA. Area traffic control by computer in Madrid. Traff. Engng & Control, 1970, *12* (3), 132–4.

7. FUEHRER H H. Area traffic control, Madrid. Paper presented at 1st Symposium International sur la regulation du traffic, Versailles. June 1970 (IFAC/ICIP).

8. WEBSTER F V and B M COBBE. Traffic signals. Ministry of Transport and Road Research Technical Paper No 56. London 1966 (HM Stationery Office).

9. HOLROYD JOYCE and J A HILLIER. The Glasgow experiment: PLIDENT and after. *Department of the Environment, RRL Report* LR 384. Crowthorne, 1971 (Road Research Laboratory).

10. HOLROYD JOYCE and D OWENS. Measuring the effectiveness of area traffic control systems. *Department of the Environment, RRL Report* LR 420. Crowthorne, 1971 (Road Research Laboratory).

11. WILLIAMS D A B. Area traffic control in West London. 1. Assessment of first experiment. Traff. Engng & Control, 1969, *11*, (3), 125–9, 134.

12. WHITING P D. The Glasgow traffic control experiment: interim report on SIGOP and TRANSYT. *Department of the Environment, RRL Report* LR 430. Crowthorne, 1972 (Road Research Laboratory).

13. OWENS D and JOYCE HOLROYD. The Glasgow experiment: Assessments under light and very low flow conditions. *Department of the Environment, TRRL Report* LR 522. Crowthorne, 1972 (Transport and Road Research Laboratory).

14. HOLROYD JOYCE. Comparison between a dynamic signal plan generation system of area traffic control and a fixed-time system. *Department of the Environment, TRRL Report* LR 487. Crowthorne, 1972 (Transport and Road Research Laboratory).

15. WAGNER F A. Improved Criteria for Traffic Signal Systems in Urban Networks. NCHRP Report 124, Highways Research Board, Washington. 1971.

16. KAY P C M and D E CASTLE. Plan changing with TRANSYT. Symposium on Road Traffic Simulation, University of Birmingham. September 1971.

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ABSTRACT

Strategies for area traffic control systems: present and future: JOYCE HOLROYD and D I ROBERTSON: Department of the Environment, TRRL Report LR 569: Crowthorne, 1973 (Transport and Road Research Laboratory). Different techniques for co-ordinating traffic signals in an area have been subjected to full-scale tests by the Transport and Road Research Laboratory. The characteristics of the techniques and results of the tests are summarised in this report. It is concluded that the case for using traffic-responsive systems is not proved because fixed-time plans based on historical data and calculated off-line by a technique such as TRANSYT, the COMBINATION METHOD or SIGOP, gave a performance at least as good as any other technique tested and would have been less expensive to install.

Possible future developments in traffic-responsive control strategies are reviewed.

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