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QUEUE MANAGEMENT PROJECT
Testing strategies using the Model

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CONTENTS

1 INTRODUCTION

This Working Paper is one of a series representing work under an SERC grant on queue management strategies for urban traffic control systems whose objectives are:-

(i)to generalise the strategies developed in an earlier study of queue management,
(ii)to develop a computer graphics based representation of queue propagation and management;
(iii)to test the strategies' applicability and performance in UK networks;
(iv)to investigate their incorporation into standard signal optimisation programs.

Clark (1991) in WP 343 describes the graphics model developed at ITS as a queue-management tool for traffic engineers. In order to calibrate the model, and later implement a suitable queue management strategy recommended by the model, a small oversaturated urban traffic network was required.

Six possible sites in the West Yorkshire region were suggested by HETS (West Yorkshire Highway Engineering and Technical Services) for consideration. Wellington Street in Leeds city centre was identified as the most suitable being a linked series of three signalized junctions where blocking-back was commonplace, parking violations were minimal and an adequate filming position was available.

The initial work was conducted in three stages:-

(i)an initial survey designed to collect before data, and data for model calibration purposes (Section 2);
(ii)the development of a series of strategies to be tested in the model and on site (Section 3);
(iii)the testing of one of these strategies on site (Section 4).

As a result of staffing problems, it was not possible to test the strategies with the final version of the model before testing them on site, or to test the full set of strategies on site. The implications of this are discussed in Section 5.

2 WELLINGTON STREET SURVEY I - 26 SEPTEMBER, 1990

A survey during the evening peak was conducted at the three junctions on Wellington Street on Wednesday 26th September 1990. The aim of the survey was:

(a)To collect data for calibrating and running the graphics model.

(b)To provide data on journey times for a "before and after" survey, to test a recommended queue management strategy.

<u>Objective (a).</u> In order to collect data which could be used to run and calibrate the graphics model it was necessary to measure queue lengths, as follows:

(i)queue length at end of each red light.
and(ii)maximum queue length in each cycle. (If greater than i).

(For a description of the model outputs see TN 295).

A sample of the data collection form for the queue length survey is included in Appendix A.

Also for objective (a) it was necessary to collect the input data needed to run the model. It was decided that for simplicity the model would continue to use Greenshields' relationship. This meant that for the speed of traffic (u_i):

$$u_i = u_f * (1 - {}^{k_i}/_{k_j})$$

and for the speed of starting and stopping waves (u_w):

$$u_w = q_i (k_i - k_j)^{-1}$$

where:-

u_f is free flow speed
k_j is jam concentration
k_i is the concentration associated with the input or output flow, q_i
u_i is the speed associated with the input or output flow q_i.

Consequently, the data input required by the model was relatively simple. That is, for each link there will be fixed data (k_j and u_f) and variable data (k_i).

Given Greenshields' linear u-k relationship, the q-k curve is then parabolic and k_i can be calculated from a measure of q_i, once k_j and u_f are known. The value k_i is calculated by solving:

$$u_f.k_j - \frac{u_f}{k_j} k_i^2 - q_i = 0$$

(For a more detailed explanation see Clark (1991) and Al-Madani (1992)).

TN 296 reports on surveys which measured the fixed traffic parameters, jam density (k_j) and free flow speed (u_f) for each link on the network. The report also describes other measurements such as the speed of traffic at saturation flow and the speed of a starting wave on a sample link. The aim was to investigate the validity of incorporating Greenshields' relationship into the graphics model. The results, as described in the report, were very encouraging.

The cycle times were not normally the same at all junctions, but on the day of the survey HETS agreed to operate all three intersections on Wellington Street on a 90 second cycle time. During the survey input flows were counted in 2 1xnute intervals between 16.15 and 17.45 hrs. The counts were classified into "cars" and "all other vehicles". Motorcycles and bicycles were negligible and were not counted. Figure 1 provides a summary of the input flows into the network measured on 26th September, 1990 and Figure 2 shows the turning movement proportions at each stopline. A sample of the data collection form for the input counts is included in Appendix B.

For objective (b) traffic was video filmed as it proceeded along Wellington Street. Two views were recorded using two cameras, which together covered all three junctions and included the full length of two principal links along Wellington Street.

The video films were later analysed taking a sample of vehicles to obtain journey times along Wellington Street, westbound. The results are presented in Section 4. The films were also used to obtain turning movement proportions at each of the three intersections.

3TESTING STRATEGIES FOR WELLINGTON STREET

Three queue management strategies plus the existing signal timings were selected for testing using the model. Figure 3 illustrates the signal timings and the space-time diagrams for each of the four options. A sample of starting wave speeds on each of the two internal links were measured from video and the results were:

Yorkshire Post to Lisbon Street:	Mean = 5.63 m/s; S.D. = 0.55; CoV. = 9.7%
Lisbon Street to Northern Street:	Mean = 5.31 m/s; S.D. = 0.97; CoV. = 18%

The evening peak plan operated by H.E.T.S. using a 90 second cycle time is shown in Figure 3. The average starting wave from the Yorkshire Post junction arrived very close to the end of the ahead stage for Wellington Street and it was not uncommon for starting waves to arrive during a stage change. Previous work in Bangkok (May et al 1988) had shown that this was undesirable because it led to drivers violating the red signal. At Northern Street the starting wave from the Lisbon Street junction arrived in the middle of the ahead stage for Wellington Street traffic.

Three strategies were devised for testing in the model based on the principles set out elsewhere (May, 1991). Each strategy involved careful alterations to the offsets, but the `splits' used by the HETS at each junction were maintained.

Strategy 1 was based on the queue management ideas developed and tested in Bangkok. The offset between the Yorkshire Post and Lisbon Street junctions was altered such that, with 95% confidence, the starting wave would arrive upstream just before the end of the ahead stage on Wellington Street. The same strategy was applied to the offset between the Lisbon Street and Northern Street junctions.

The aim of Strategy 2 was also to ensure that starting waves did not arrive upstream during stage changes; but unlike strategy 1, the offsets were arranged such that starting waves would arrive upstream just after the start of the ahead stage on Wellington Street.

Strategy 3 was different from both the above in that offsets were selected to ensure that starting waves arrived during the stage giving priority to traffic from the side streets entering/crossing Wellington Street. As with strategy 1 the offsets were altered such that, with 95% confidence, starting waves arrived upstream just before the next stage change.

Tests using an early version of the model showed that Strategy 3 produced by far the longest queues; but there appeared to be little difference between the length of the queues produced by Strategies 2 and 1. In light of the success of tests in Bangkok and given that the model had not been fully calibrated it was decided not to select the promising Strategy

2 but to err on the side of safety and opt for implementing Strategy 1 on Wellington Street.

4 WELLINGTON STREET SURVEY II - 11 APRIL, 1991.

The signal plans for Strategy 1 were given to the UTC centre for implementation during the evening peak on Thursday 11th April 1991. As with the previous survey in September 1990 traffic on Wellington Street was filmed using two video cameras. These films were analysed, as before, to obtain turning movement proportions and average journey times through the network. Input flows and queue lengths were also measured. Figures 4 and 5 show the input flows and turning movement proportions, respectively.

On-street observation on the day of the survey confirmed that the queue-management strategy (1) operated as planned with queues arriving at the upstream junctions at the expected times in each cycle. In particular the Lisbon Street junction was always clear during stage changes which was not always the case under the standard HETS plan.

One problem with Strategy 1, however, was that during peak surges in traffic flow the vehicles entering from Northern Street filled the remaining available space in Wellington Street. The result was that the main ahead movement on Wellington Street could move across the Northern Street junction only when the starting wave arrived from the downstream Lisbon Street junction. As can be seen in Figure 3, this allowed only a few seconds of flow before the end of green. However, this situation did not repeat itself over successive cycles and the extra queue length on Wellington Street quickly reduced to its expected manageable length.

Under the standard HETS plan this situation did not arise during the surges of traffic flow because the starting wave from Lisbon Street arrived at the Northern Street junction in the middle of the main "ahead" stage for Wellington Street. On the other hand, the offset appeared to be less effective when flows were at their expected level, and this was confirmed by the travel time surveys.

Travel Times

A random sample of greater than 50 vehicles was identified from the video films and each vehicle was timed through the internal links of the network. Timing points used were the stoplines at the upstream and downstream end of the link. This was done for both the Sept 1990 and April 1991 surveys. Table 1 shows a comparison of the journey times for the two surveys. (A `d' test was the appropriate statistical procedure as the samples were each greater than 50).

Table 1 - Journey Times (seconds) on Internal Links
(a) Wellington Street (Northern to Lisbon Street Junctions)

	Standard control Sept. 90	Strategy 1 April 91
Sample size	57	60
Sample mean	22.2	16.2
Variance of mean	9.1	2.4

d = 1.78 (p > 0.05 = 1.96)

(b) Wellington Street (Lisbon Street to Yorkshire Post Junctions)

	Standard control Sept. 90	Strategy 1 April 91
Sample size	57	59
Sample mean	42.1	40.6
Variance of mean	13.9	10.3
d = 0.30	(p > 0.05 = 1.96)	

For both the mid-link (Northern Street to Lisbon Street) and the exit link (Lisbon Street to Yorkshire Post) the average journey times were lower using the queue-management strategy (1) compared with the standard HETS control.

For the mid-link travel time was 27% lower than with the standard control, and for the exit link 5%. For the two links combined, the reduction was 12%. While none of these was significant at the 95% confidence level, the reduction on the mid link was particularly marked.

Flows

The opportunity was also taken to re-survey traffic flows and turning movements. The resulting data are recorded in Figures 4 and 5. Table 2 presents a brief comparison of the flows in the two surveys, and shows increases of between 2% and 7% in the three links on Wellington Street.

Table 2 - Percentage increase in vehicle flow, Sept. 1990 to April 1991

Wellington Street (Entry link)	106.9%
Wellington Street (Mid-link)	104.8%
Wellington Street (Exit link)	102.3%

Discussion

Referring again to the differences between Strategy 1 and the standard HETS control (as shown in Figure 3), it can be seen that the offset for the exit link between the Yorkshire Post and Lisbon Street junctions was changed only slightly to avoid stationary queues interfering with stage changes at the Lisbon Street junction. It is interesting to note, then, that although there was a higher traffic volume during the implementation of Strategy 1 on April `91, there was a slight reduction in average journey times.

The offset for the mid-link between Lisbon Street and Northern Street junctions was altered quite dramatically and the survey results suggest that the operation of Strategy 1 was producing some clear benefits. The average journey time fell from 22.2 minutes to 16.2 minutes while the flows increased by 4.8%. This finding is consistent with the expectation that the greatest benefits to accrue from implementing Strategy 1 would occur in the mid-link on Wellington Street.

By re-examining Figure 3, it can be seen that the standard HETS control effectively used a queue management strategy the same as Strategy 1 for the exit link, but not for the mid-link.

5 CONCLUSION

These initial results suggest that it should be possible to obtain significant time savings by adopting strategies more carefully designed to reduce the adverse effects of queues. Subsequent work on the calibration of the model involved further testing of the three strategies developed in Section 3, and demonstrated that, in practice, Strategy 2 would be more effective than Strategy 1 in managing queues, and that Strategy 3, slightly modified, would be more effective still by providing for queue storage on the side links (Clark and Montgomery, 1991). It is hoped to test Strategy 3 further on site as part of a subsequent research project.

6 REFERENCES

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APPENDIX A

WELLINGTON STREET SURVEY

DATE

LINK

DISTANCE	MARK	TIME AT END OF RED							

DISTANCE	MARK	TIME AT END OF RED							

APPENDIX B

WELLINGTON STREET SURVEY

DATE

LINK

TIME	COUNTS	
	CARS	OTHERS
4.15 - 4.17		
4.17 - 4.19		
4.19 - 4.21		
4.21 - 4.23		
4.23 - 4.25		
4.25 - 4.27		
4.27 - 4.29		
4.29 - 4.31		
4.31 - 4.33		
4.33 - 4.35		
4.35 - 4.37		
4.37 - 4.39		
4.39 - 4.41		
4.41 - 4.43		
4.43 - 4.45		
4.45 - 4.47		
4.47 - 4.49		
4.49 - 4.51		
4.51 - 4.53		
4.53 - 4.55		
4.55 - 4.57		
4.57 - 4.59		
4.59 - 5.01		

WELLINGTON STREET SURVEY

DATE

LINK

TIME	COUNTS	
	CARS	OTHERS
5.01 - 5.03		
5.03 - 5.05		
5.05 - 5.07		
5.07 - 5.09		
5.09 - 5.11		
5.11 - 5.13		
5.13 - 5.15		
5.15 - 5.17		
5.17 - 5.19		
5.19 - 5.21		
5.21 - 5.23		
5.23 - 5.25		
5.25 - 5.27		
5.27 - 5.29		
5.29 - 5.31		
5.31 - 5.33		
5.33 - 5.35		
5.35 - 5.37		
5.37 - 5.39		
5.39 - 5.41		
5.41 - 5.43		
5.43 - 5.45		
5.45 - 5.47		

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