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Working Paper 306

August 1990

PILOT SURVEY

(feasibility study of several data collection techniques)

Queue Management Strategies

for Urban Traffic Control Systems

D J Quinn and K Topp

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1. BACKGROUND

1.1 Advances in traffic signal optimization have produced increases in the capacity of urban road networks, but recent growth in demand has meant that many junctions operate at or above saturation levels. Delay costs increase dramatically when queues extend to block upstream junctions and queue management strategies are now required to ensure that local traffic signals operate effectively when oversaturated conditions occur.

1.2 The aims of this SERC-funded project are as follows:

(a) To generalise the strategies for queue management that were developed and tested empirically in Bangkok (See ITS WP 249 and WP 251);

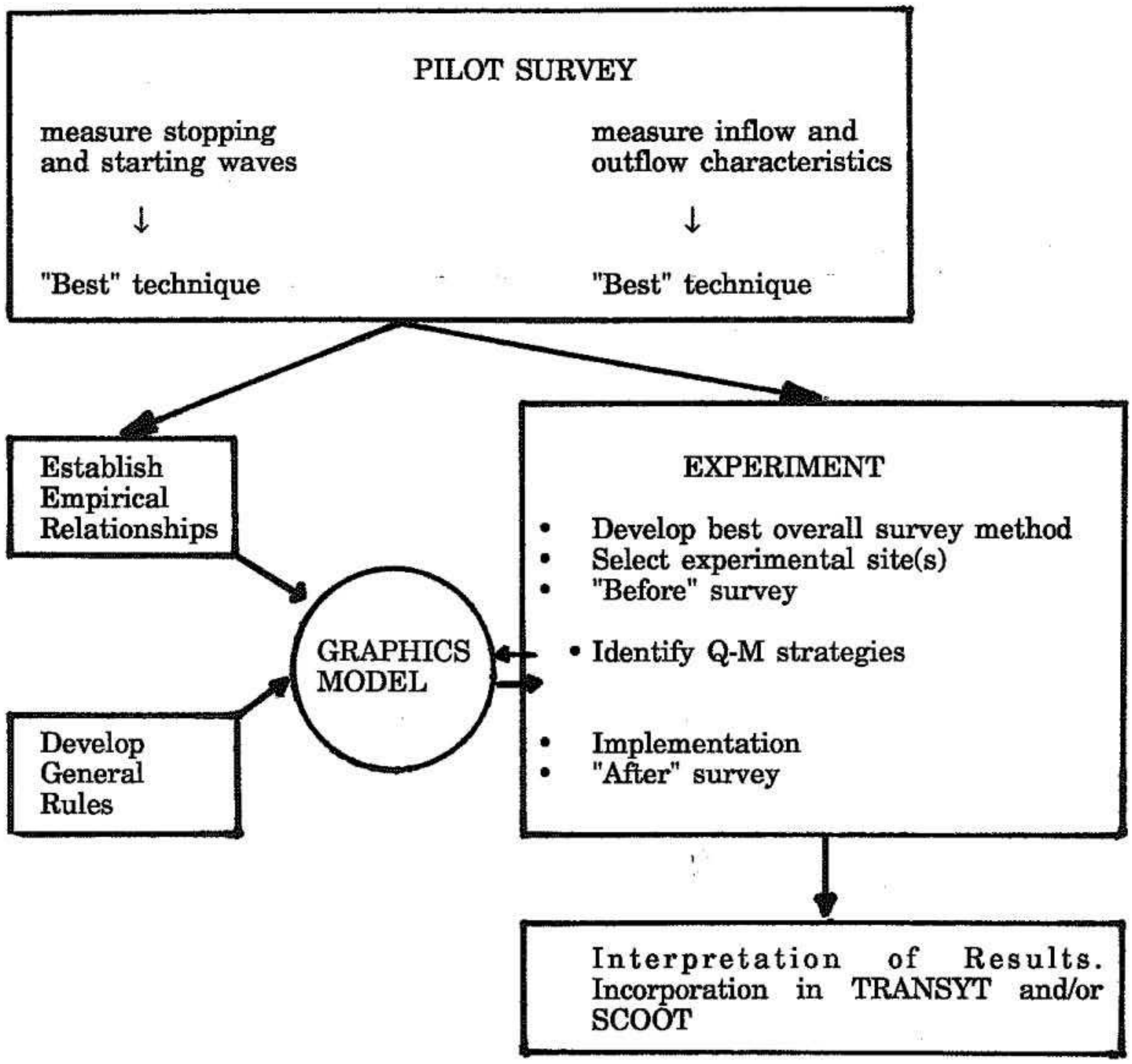
(b) To develop a computer graphics model to represent queue propagation;

(c) To test the strategies' applicability and performance in UK networks;

(d) To investigate their incorporation into standard signal optimization programs.

1.3 Figure 1 outlines the project structure.

FIGURE 1: PROJECT STRUCTURE



2. INTRODUCTION

2.1 In order to develop a generalised strategy for queue management it is necessary to understand the relationships between speeds of stopping/starting waves and the characteristics of the relevant traffic conditions both upstream and downstream of these shock-waves.

2.2 Clearly, stopping/starting wave speeds are related to the flow of traffic, but a given flow could correspond to more than one speed and density (or occupancy). Therefore a second characteristic ought to be measured.

2.3 Occupancy was selected as the second parameter, given that it is most readily measured using existing detector technology and because, like flow, it is a time-based parameter. Further it may be possible to incorporate successful queue-management strategies into an on-line UTC system, such as SCOOT, making use of existing flow/occupancy detectors.

2.4 As a first step, a pilot survey was needed to test the feasibility and accuracy of a range of techniques for collecting data relating to the formation and dissipation of traffic queues, on a single lane within a signal-controlled network.

3. TRAFFIC PARAMETERS AND DATA COLLECTION TECHNIQUES

3.1 Three techniques (manual, video, automatic) were used to measure stopping/starting wave speeds and to collect flow/occupancy data for the relevant traffic conditions. Table 1 outlines the parameters which were measured by each of the three possible techniques.

Table 1: Parameters and Data Collection Techniques

	Occupancy	Flow	starting wave speed	stopping wave speed
Manual	X	✓	✓	✓
Video	✓		✓	✓
Detector	✓	✓	✓	✓

3.2 Apart from investigating the feasibility of using each data collection technique, another important aim of the pilot survey was to identify the best overall data collection method which could be employed in a full experiment and which, initially, could be used to obtain the data needed to establish empirical relationships between wave speeds and flow/occupancy data[1] (See Figure 1).

[1]The pilot survey site was re-surveyed for a 4-day period (2-5 July 1990) one week after the pilot survey using a streamlined data collection method. Analysis of this data forms part of a PhD research project at ITS, Leeds University, being carried out by Hashim Al-Madani.

3.3 From Table 1 it can be seen that the pilot survey was designed to facilitate a full comparison between the three techniques for measuring the speeds of stopping and starting waves, and in particular, to examine how well detectors compared with both video and manual observations.

3.4 In terms of traffic flow, the aim was to establish the accuracy of detectors compared with a manual counting technique (i.e. either on-street or from video).

3.5 The use of a manual on-street method for measuring occupancy was considered unnecessary and impracticable. However, it was considered useful to compare occupancy data from detectors with a video technique using a slow-motion analysis.

4. SITE REQUIREMENTS

4.1 Physical/Geometric characteristics

- 60 to 100 meters,
- straight level single lane link,
- no significant side street movements,
- high buildings for filming,
- useful street furniture (distance markers).

4.2 Traffic control aspects

- signalised junctions at upstream and downstream ends of the link,
- no parking during survey period (i.e. pm.peak),
- fixed-cycle plan (preferred),
- occupancy/flow detectors along link (see Section 5).

4.3 Operational characteristics

- the downstream exit should be free from blockages and restrictions (i.e. long periods of saturation flow should occur regularly);

- ideally, the maximum queue length each cycle should buildup gradually over the peak period and extend to the upstream end of the link (i.e. upstream detector) during a peak 15 minute period.

5. DETECTOR OPTIONS

5.1 A site was sought which had a sufficient number of existing detectors to negate the need for any additional loops. The West Yorkshire Highways, Engineering and Transportation Services (HETS) has authority for traffic signal installations in the West Yorkshire area, which includes:

- isolated vehicle-actuated (V/A) signals
- UTC area with fixed-time signal plans
- SCOOT systems.

5.2 V/A sites offered the possibility of using three (XYZ) loops positioned upstream of a stopline. However, two or more of the loops are usually wired together and, in this situation, useful data can be retrieved when only a single loop remains connected to the control box (i.e. the wires connecting the other loops must be disconnected). A further limitation is that the XYZ loops are normally found within approximately 30 meters of a stopline and not at the upstream entrance to a link.

5.3 Generally, detectors are not required for a fixed time UTC system and in the case of SCOOT, a single detector only is needed at the entrance to each link. However, within a recently installed SCOOT system there are often several sites that were formerly under V/A control. Under these conditions, therefore, it would be possible to identify a single link containing several detectors already installed at key locations.

5.4 Engineers at HETS supplied a list of nine SCOOT sites with dormant V/A detectors. Of these only two sites met all or most of the site requirements (see Section 4) and from these two only one site (in Wakefield) had V/A detectors which could be re-activated.

5.5 Figure 2 shows the layout of the selected link in the Bull Ring, Wakefield. The link offered two further advantages:

- an additional detector downstream of the stopline,

- fixed-time signal plans even though SCOOT control was available.

The disadvantages were that:

- the distance between the stopline and the upstream SCOOT detector was only 70 metres;

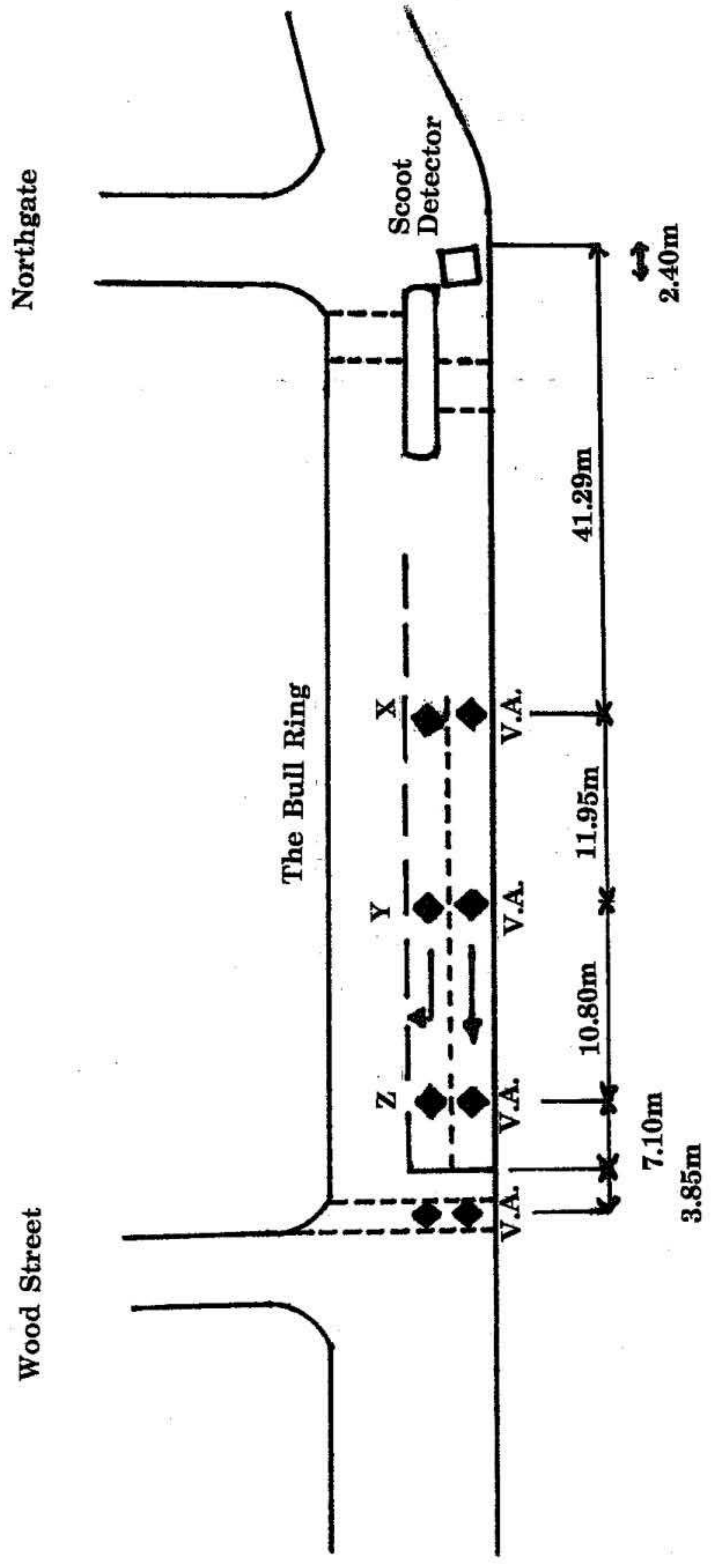
- the selected link had a right-turn at the stop-line;

- V/A detectors covered two lanes;

- all three V/A detectors (XYZ loops) were wired together, and therefore, useful data could be collected from one loop only;

- the SCOOT and V/A loops were connected to two different signal control boxes, which added to the problem of synchronization (Section 9).

Figure 2 - PLAN OF THE BULL RING, WAKEFIELD



6. DATA COLLECTION - MANUAL TECHNIQUE

6.1 The pilot survey was conducted on Thursday 21st June 1990 between 4 and 6 pm. Five observers were employed to stand on-street and record the exact time when stopping and starting waves passed over pre-determined points along the Bull Ring link. The observation points are illustrated in Figure 3. One observer, positioned at the stopline, recorded the start of each starting/stopping wave. Three other observers were positioned at detector locations (including the SCOOT detector) and a fifth observer stood at a fixed point mid-way between the upstream V/A detector ("X" loop) and the SCOOT detector. (A short exercise in Leeds city centre confirmed that one person could record the passage of stopping and starting waves at one observation point only). Another observer recorded signal change times.

6.2 A briefing session was held on the morning before the survey and each observer was given a split-second stop watch and very clear definitions of when to make entries on the prepared data collection forms (see Appendix A).

7. DATA COLLECTION - VIDEO TECHNIQUE

7.1 From an earlier analysis of other video tapes it was verified that the exact position of the end of a queue can not be estimated accurately from a general view of a link, due to problems of parallax. Therefore, it was necessary to position three cameras along the studied link with fields of vision tightly focused on the manual observation points.

7.2 An additional camera provided a general view of the entire link, but only for purposes of identifying the origins and destinations of vehicles, recording any events which might have affected the passage of shock waves along the link, and if needed, to co-ordinate the other three cameras.

7.3 Permission was granted by building managers/owners to film from three suitable positions (Appendix B includes a list of the relevant names and addresses). Figure 3 shows the fields of vision for each of the four cameras.

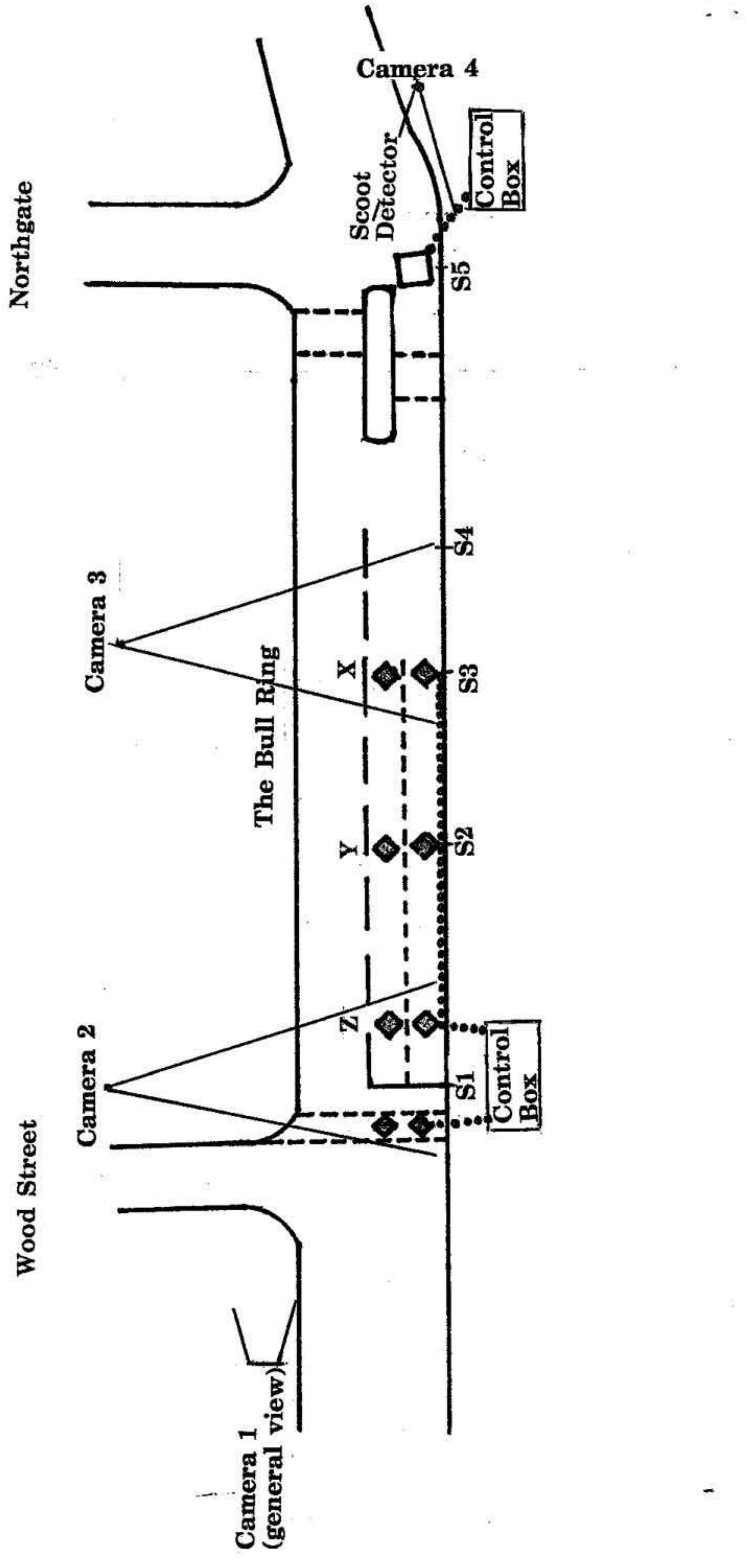
7.4 Camera 4 was positioned on-street very close to the SCOOT detector. Occupancy was measured from the film using a slow-motion analysis, and flow was also counted in order to complete the comparison with the flow/occupancy data retrieved from the SCOOT detector.

7.5 Cameras 2 and 3, together with camera 4, recorded the passage of stopping and starting waves from the stop line, through the manual observation points, and over the SCOOT detector installation at the upstream end of the link.

8. DATA COLLECTION - DETECTORS

8.1 The SCOOT detector provided data on the passage of stopping/starting waves and flow and occupancy. Unfortunately, on the day of the pilot survey the HETS engineers were unable to rewire any of the three V/A detectors (i.e. XYZ loops) in order to produce any useful data. However, they were able to perform this task later (2nd July 1990) for purposes of collecting data required to establish an empirical relationship.

Figure 3 - DATA COLLECTION POINTS ON THE BULL RING (21-06-90)



S1 to S5 = positions for manual observers

8.2 Although the detector situated downstream of the stopline was not needed for the purpose of making comparisons between data collection techniques, it was nonetheless activated on the day of the pilot survey in order to test the feasibility of synchronizing detectors connected to two separate signal control boxes (see Section 9).

8.3 All the V/A detectors were connected to a control box situated close to the stopline, while the SCOOT detector was linked to a control box close to the upstream end of the link. In order to collect flow/occupancy data the engineers at HETS designed and assembled two single-board computers which were connected to each of the control boxes.

8.4 The two single-board computers were started at the same instant using two-way radios (alternatively a third person with a stop-watch could be used to give a simple visual signal (e.g. dropping of an arm) to indicate the exact moment when data collection should commence).

8.5 The data from the single-board computers were later off-loaded onto a micro-computer at the offices of HETS.

9. SYNCHRONIZATION

9.1 The synchronization of all timing devices (i.e. stopwatches, timing facilities in cameras and clocks in detectors) presented a formidable task.

9.2 On the day of the pilot survey the timers in all cameras were started simultaneously, on-street, and the cameras were then carried to their filming positions. Unfortunately, it was found that the cameras (and the timers) switch themselves off after about 6 minutes when not set to the recording mode. It was necessary therefore to restart the timers in each camera (once positioned) and note the offset with the master stopwatch (see table 2).

9.3 Therefore, although the master stopwatch was started at 4 pm along with the timer in camera 4 (over the SCOOT detector) the timer in camera 3 was started exactly 10 minutes after the master stopwatch and the timer in camera 2 was started exactly 15 minutes after the master stopwatch (camera 1 had no stopwatch facility).

9.4 The handheld stopwatches used by the on-street observers were started at the same instant when the clocks for the single-board computers (i.e. V-A and SCOOT detectors) commenced, which was precisely 22 minutes and 8 seconds after the start of the master stopwatch.

9.5 A full list of the equipment and manpower need for the pilot survey is found in Appendix C.

Table 2: **Offset between Timing Devices (21/7/90)**

	min	sec	1/100th
master stopwatch	00	00	00
timer in Camera 2	+ 15	00	00
timer in Camera 3	+ 10	00	00
timer in Camera 4	00	00	00
clocks in detector boxes	+ 22	08	00
on-street stopwatches	+ 22	08	00

10. ANALYSIS METHOD

Occupancy

10.1 Ten minutes of occupancy data was collected from the camera focused on the SCOOT detector. The slow motion facility on the camcorder was used to measure the time period during which the video picture of the detector was occupied by a vehicle. The information obtained from the SCOOT detector itself, was the time, to the nearest tenth of a second, at which the detector was activated and the time at which it was deactivated. The percentage occupancies from the video tape and the SCOOT detector were calculated for each minute and the whole ten minute period.

Flow Counts

10.2 Counts at the SCOOT detector were collected for three ten-minute periods. The information was obtained by counting the number of times that the SCOOT detector was activated. A stationary queue was present over the detector, at some stage during each of these periods. Motorbikes and cyclists were excluded from the count obtained from the video tapes.

Stopping and Starting Waves

10.3 The manual observers recorded the time, to the nearest hundredth of a second, that the stopping and starting waves reached their stations. (See Appendix A for definitions).

10.4 The time the stopping and starting waves reached stations 1, 3, 4 and 5 (Figure 3) were also transcribed from the video tapes. There was no video camera coverage of the link between stations 1 and 3, nor between 4 and 5. Thus in order to determine when an actual stopping / starting wave had reached the stations, the video tapes from cameras 2, 3 and 4 were viewed simultaneously. This technique permitted the stopping and starting waves to be followed from station 1 to the end of the queue.

10.5 The output from the SCOOT detector was also used to determine when the stopping and starting waves had reached the detector (i.e station 5). When a stopping wave was recorded at the SCOOT detector, there was a minimum of five seconds between the time the detector was activated and the time it was deactivated. The activation and deactivation times corresponded to the times the stopping and starting waves reached station 5, respectively.

11. RESULTS OF THE COMPARISONS

Occupancy

11.1 The percentage occupancy obtained from the video tape, for the ten minute period, was 1.8% lower than that obtained from the SCOOT detector, Table 3. The difference between the percentage occupancy obtained from the two methods, for the one minute periods, ranged from 0.86% to 3.67%, and the percentage occupancy of the data collected from the video tape was always lower than that obtained from the SCOOT detector.

Table 3: The percentage occupancies obtained from the SCOOT detector and transcribed from the video tape

Time period	Video % Occupancy	SCOOT % Occupancy
1	58.8	62.5
2	57.0	58.0
3	16.0	19.2
4	29.3	31.5
5	33.6	34.5
6	27.5	30.5
7	22.0	23.0
8	17.5	19.2
9	16.3	17.2
10	0.6	1.5
1-10	27.9	29.7

11.2 A paired t-test was performed on the video tape data and the SCOOT detector data obtained for the ten one minute periods. The probability that the means were the same was 0.0005, and thus the data obtained from the SCOOT detector was significantly different from that obtained from the video.

Flow Counts

11.3 The number of vehicles counted by the SCOOT detector was always less than the number of vehicles counted from the video tape, Table 4. A paired t-test on the counts obtained from the video analysis and the SCOOT detector was insignificant at the 5% probability level (Pr > 0.0533).

Table 4: **<u>The vehicle count in three ten minute periods at the SCOOT detector and transcribed from the video tape.</u>**

Time interval	Video Count	SCOOT Count
1	83	81
2	94	90
3	85	80

Starting and stopping waves

11.4 At stations one, three and four the data obtained from the video tapes were compared with that obtained by manual observers. A three-way comparison between the data obtained from manual observers, video tape and the SCOOT detector was made at station five. The comparison of methods at the different stations started with the same stopping wave and finished with the same starting wave. However, the number of waves recorded by the different methods at the same stations differed, Table 5.

Table 5: **<u>The number of stopping waves detected at the different stations by manual observers, video tape analysis and detectors</u>**

Station	Manual	Video	Detectors
1	36	36	
3	22	22	
4	24	22	
5	20	18	25

11.5 A t-test was used to compare the means of the time the stopping and starting waves reached a particular station measured by manual observers and transcibed from video tapes. There was no significant difference between the means recorded by the two techniques. An analysis of variance test revealed that there was no significant difference between the means obtained from the observers, video transcription or from the SCOOT detector for either the stopping or starting waves at station five.

12. DISCUSSION

Occupancy

12.1 The use of the slow-motion facility in a video recorder/player to measure occupancy from video-film was time-consuming (about one hour to analyse 10 minutes of film) and was found to be inaccurate because:

- it was difficult to determine from the film exactly when the short section of road (i.e. the detector installation) was occupied and not occupied, and because

- human reaction-time introduced further data errors.

Flow Counts

12.2 The minor difference (statistically insignificant at the 5% probability level) between the flow counts using two techniques (i.e. SCOOT detector and manual from video-film) can be explained by the tendency for the SCOOT detector to undercount vehicles during highly congested periods. Table 2 shows that counts from the detector were consistently lower than the manual counts taken from the video-film for the same time intervals. This undercounting occurs whenever the tail of a leading vehicle fails to clear the SCOOT detector before the front of a following vehicle first arrives at the detector installation.

Stopping and Starting Waves

12.3 There was no statistically significant difference between the means obtained from the three techniques and there was little difference between the variances.

12.4 However, the number of waves measured by the three techniques at station 5 (i.e. at the SCOOT detector) differed because some drivers stopped on the detector itself to allow passenger to alight. These events were not identified as stopping/starting waves in the video analysis because of the method used to reduce data from the several films and in the case of the observers standing on-street, these events could have been missed or ignored.

12.5 Also, the time of the stopping wave recorded by the SCOOT detector is earlier than that recorded by either the observer or transcribed from the video tape. In most circumstances, the time of the starting wave recorded by the detector is later than that recorded by either of the two other methods. This is due to the fact that the SCOOT detector is recording when the front-end of the vehicle moves over the detector and when the vehicle's rear-end leaves the detector, rather than the time the vehicle actually stops and starts.

12.6 Finally, and most importantly, it was discovered that the presence of several on-street observers influenced driver behaviour when joining the rear of queues or when moving-off after a stationary period.

13. CONCLUSION

13.1 From the above discussion it is clear that detailed video-film coverage of a link offers a suitable and accurate technique for monitoring the passage of stopping and starting waves and it can offer, also, the opportunity to check flow data obtained from any detectors thought to undercount during periods of traffic congestion.

13.2 Additionally, the video films can be used to identify any shuffling by vehicles within a stationary queue as well as for turning counts and identifying when specific vehicles pass over flow/occupancy detectors.

13.3 For measuring occupancy, however, video-films are unsatisfactory and the data is best obtained from occupancy/flow detectors.

13.4 It was shown that a SCOOT detector could be used to identify automatically the passage of stopping/starting waves, should this be required later in the main experiment. But, it must be remembered that the detector monitors when a vehicle first leaves or arrives at the detector installation and not the exact moment when the vehicle itself stops or starts.

14. RECOMMENDATIONS FOR THE SECOND SURVEY (2ND - 5TH JULY)

14.1 The aim of the second survey is to collect data that will be used to establish an empirical relationship (see paragraph 3.2). The time the stopping and starting waves reach designated points will be transcribed from video tapes. In order to avoid the problems of parallax, three video cameras will be sited in high buildings parallel to the link. A plan has been devised to overcome the problems of synchronizing the cameras and the detectors, Appendix D. Vehicles flows will also be transcribed from the video tapes

14.2 Another camera will film the entire link. It will be used to coordinate the other three cameras and provide information on any incidents that might occur and to identify vehicles using the right-turn lane.

14.3 The percentage occupancy relating to the stopping/starting waves will be calculated from data obtained directly from the relevant detectors (i.e. downstream of the stopline, the midlink "X" detector, and the SCOOT detector).

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APPENDIX A

DEFINITIONS

Stopping Wave

Record the time in minutes, seconds and hundredth of seconds, at which a vehicle stops at your station. If a vehicle does not stop exactly on your station record the next vehicle that stops just upstream.

Starting Wave

Record the time in minutes, seconds and hundredth of seconds that the vehicle you observed stopping starts to move.

Note

Please do not move from your exact position on street, as your body is a marker for the video analysis.

NB The idea of using the bodies of enumerators as markers was abandoned and replaced with fixed-points (i.e. traffic control lines painted on kerbs).

APPENDIX B

BUILDING MANAGERS, BULLRING, WAKEFIELD

Camera 1: **MARYGATE HOUSE**

owned by: GRE properties
17 Burton Street
London W1X 7AH

tel: 071-493 9596

contact: Mr RJ Barrett

agents letting the offices:

Vickers Orriss
Crown Court
Wakefield WF1 2SS

tel: 0924-291500

contact: Mr Lee Carnley

Camera 2: **PIONEER MUTUAL HOUSE**

owned by: Pioneer Mutual
The Bull Ring
Wakefield WF1 1HA

tel: 0924-371 234

contact: Mr Tom Pyle

Camera 3: **NATIONAL WESTMINSTER BANK CHAMBERS**

owned by: National Westminster Bank
8 The Bull Ring
Wakefield WF1 1HA

tel: 0924-371 656

contact: Mr Farmery

offices on topfloor rented by:

Nichols Hardie and Company
National Westminster Bank Chambers
8 The Bull Ring
Wakefield WF1 1HA

tel: 0924-376 701

contact: Jan

APPENDIX C

EQUIPMENT AND MANPOWER

4	Video-cameras and recorders (at least three with split-second stopwatch facility)	
4	Tripods	
9	Stopwatches	
2	Single-board computers	

Miscellaneous - chalk, tapemeasure, traffic cone

9	People	3 to set-up cameras and 1 HETS engineer to install single-board computers 5 observers

APPENDIX D

TIMETABLE / SYNCHRONIZATION METHOD

14.00	Leave University with equipment; drive to Wakefield
14.40	Drop-off equipment on Bull Ring person 1 - guard equipment person 2 - collect key from Vickers Orriss person 3 - park car
15.00	Place 4 tripods in appropriate filming positions
15.30	Return all cameras "on-street" (Bull Ring). Start recording on battery power and then simultaneously start stopwatches and stopwatch facilities in Cameras. If the stopwatch facilities in the cameras are started without the cameras set to recording mode then the cameras switch-off themselves (and the stopwatches) after about 6 minutes. As 6 minutes is not enough time to carry all the cameras back to the filming position, it is necessary therefore to start recording before synchronization of the stopwatch facilities.
15.45	Cameras replaced on tripods and switched to mains power supply (except camera on-street, which continues on battery power). Some camera batteries (i.e. power-packs) have enough power for 2 1/2 hours, while others are much shorter. Note: there is no effect on recording when the power supply is changed from battery to mains.
15.50	Meet HET Engineer(s), and place the two single-board computers in the two signal control-boxes (situated at the upstream and downstream ends of the Bull Ring link).
16.00	Simultaneously start clocks in the two single board computers. This requires 3 people. Two people press switches on the single board computers while the third person holds a stopwatch and drops his/her arm at the nearest full-minute (this time is noted).
16.00 to 17.00	A full hour of data collection from detectors and video-filming.
17.00	Dismantle equipment and return to Leeds.
Next day:	collect detector information from HETS.