THE PREDICTIONS OF SATURATION FLOW REDUCTION AND EXTRA DELAY

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ABSTRACT

This report pointed out some new development in analysing effects of parking at a traffic signal area based on a real field experiment. Data collection was carried out where a parked vehicle was set up at an approach to a signalised intersection. A three lane of one way approach to a signalised intersection in Leeds, UK was chosen as the study site. Two main areas were discussed in this research report; the prediction of saturation flow reduction and the prediction of extra delay due to the presence of a parked vehicle. The new findings showed that the presence of a parked vehicle affected saturation flow; the closer the parked vehicle to the stopline the bigger the reduction of saturation flow. Moreover, extra delay was affected in the same way, it was found that the closer the presence of a parked vehicle to the stopline the larger the extra delay.

INTRODUCTION

There has been little research carried out in this area for some time. Therefore the objective of this research was to reopen this forgotten area in traffic signal capacity. However, the limited space in this paper makes it unable to present the whole results of the research, readers requiring more detailed findings may consult the references at the end of this paper.

Webster and Cobbe (1966) dealt with the effect of parking on the approach to a signalised intersection as if the lane was narrower, causing a reduction to saturation flow. However, in their work traffic was not accounted for on lane by lane basis, since at that time lane discipline was not strong. As a result, this previous work might not be appropriate for current conditions where lane discipline is strong. On the other hand, Research Report No 67 (Kimber et al, 1986) provides a tool to predict saturation flow for current conditions, based on data collected around the UK. Unfortunately, the presence of a parked vehicle was not treated. Therefore, the results of this research could usefully fill this gap.

Previous works on extra delay caused by parking were normally based on simulation results as presented by Smeed (1961), Webster and Cobbe (1966). In contrast, this research presents an analysis of real data from the field experiment.

RESEARCH METHOD

Data for this study was collected based on the field experiment. An approach of a one way street with three lanes in Leeds was chosen for the study site. A deliberately parked vehicle was used for observations. This is because it was very unlikely that naturally parked vehicles would be found in suitable numbers for experiment purposes, as their occurrences are random in time and space. Five different blockage distances were used in the experiment. Hence, the deliberately parked vehicle was placed at distances; 15 m, 30 m, 45 m, 60 m, and 75 m from the stopline.

Three video cameras were used in this observations. Two cameras were dedicated to observe the change of saturation flow from the back view, and another camera was used to observe traffic disturbance from the front view. In addition, extra delay was simultaneously measured with Number Plate Matching (NPM) method.

The analysis of the data involved saturation flow and extra delay and can be described as follows :

<u>Saturation flow</u>. As found by McDonald et al (1984) measuring saturation flow for multi lane approach is not possible using a direct manual count. Therefore, for this study video cameras were set up to record traffic passing the stopline in order to measure saturation flow. However, it was realised at the beginning of the study that a major disadvantage of using video recorders was the great deal of time needed for transcription of the recorded data. Using a video recorder does not reduce data collection time, but only transfers field work into lab/office work. Spending time for transcription can not be avoided.

Road Note 34 (RRL, 1963) describes a standard method of measuring saturation flow in the field. This method is based on manual observations; an observer has to count vehicles passing the stopline and at the same time, continuously monitor a stopwatch. At the end of a six second period the observer must record the count for that period whilst still concentrating on the traffic leaving the intersection. Often, two observers have to work together to achieve reliable results. This manual work was considered to be laborious and tedious to apply in measuring saturation flow from either direct observations or by playing back video tapes. Therefore, substituting this method, a computer program was developed to enable saturation flow to be measured from video tapes by only one person with high accuracy.

The developed program written in BASIC, actually consists of calling a clock time subroutine from MS-DOS when the keyboard is activated. Different keys are used to identify different vehicle types. This program does not count saturation flow directly but from output file can be read; type of vehicles, pcu values, headway and cumulative headway. This is in contrast to the program developed in TRRL (Wood, 1986) where saturation flow is directly resulted from the output. However, it is believed that using this output file saturation flow can be more easily estimated using a variety of methods.

In order to have accurate results in estimating saturation flow, it should be noted that data transcription was not taken from all data as it was recorded on the tapes. Any phase containing traffic problem (i.e., blocking back from downstream or any incident) was discarded. Additionally, if the lane contained less than 10 vehicles in any cycles, then the data at that lane was discarded for that cycle. The former mostly happened at the end of observations and the latter mostly occurred at the beginning of the observations. As a result, each saturation flow was derived from around twenty cycles, which was more than sufficient according to Shanteau (1986).

To estimate saturation flow a cumulative discharge profile method (Shanteau, 1986) was adopted. Saturation flow was determined graphically as the slope of cumulative discharge profile. In this analysis, for each lane a separate curve is drawn for each cycle, and each curve showed the cumulative passage time of individual vehicles. Since this method displays each vehicle head way separately rather than grouping several headways into a time interval, therefore the effect of parking on saturation flow can be clearly seen.

Extra delay. Extra delay was derived from the different of travel times. The observed travel times were calculated based on the NPM method, and therefore data was recorded using audio tapes. A matching program which was developed in the Institute for Transport Studies, University of Leeds was used. This program fits a quadratic curve through the timing bench marks as recorded on the tape. Moreover, the program produces an output file containing travel time statistics and the number of matched vehicles.

To cope with the spurious matches which always exist and can have disproportionately large effect on travel time statistics reanalysis of travel time statistics is necessary. In this study, a method based on statistical analysis was employed (May and Mont gomery, 1983). In this method to remove outliers, examining the median and inter-quartile range for each time slice of analysis. is carried out. Therefore, truncated data was obtained by estimating the standard deviation from the inter-quartile range for each time slice assuming travel times are normally distributed, and dropping all matches with travel times greater than three time of the standard deviation from the appropriate median.

RESULTS AND DISCUSSIONS

Saturation flow

Based on the analysis of saturation flow using the method mentioned previously it was worth mentioning that the presence of a parked vehicle made it more difficult to analyze the data at smaller blockage distance as the cumulative curve was found to have ripples. To overcome this problem a smoothing curve was constructed visually and than the saturation flow was determined. The ripples on the curve may well be caused by the behaviour of drivers merging in front of the parked vehicle, or improper as signation of pcu values. It was observed in the field that dif ferences in driver behaviour in perceiving the parked vehicle resulted in different merging processes. On the other hand, as signing pcu values during data transcription may lead to undesired results, since, for example, passenger car vary from a mini car to a big saloon and yet are assigned the same pcu value.

The results of measurement saturation flows (converted to equivalent straight ahead flow) are presented in Table I. This shows that under normal conditions (no parked vehicle)

Table I. Saturation flow from the experiment (pcu/h)

Blockage location	Left lane	Middle lane	Right lane
15 m	1410(0.10)	1478(0.09)	1720(0.13)
30 m	1563(0.06)	1532(0.06)	1731(0.11)
45 m	1628(0.04)	1571(0.08)	1780(0.09)
60 m	1716(0.09)	1862(0.08)	1721(0.14)
75 m	2022(0.05)	1978(0.07)	1796(0.10)
Whithout blockage	2191(0.07)	2034(0.10)	1729(0.15)
Kimber et al (1986)	1915	2055	1915

(..) = coefficient of variation

the saturation flows measured in the study site were in close agreement with the prediction of according to Research Report No 67 (Kimber et al, 1986), especially for the middle lane which was only 2 % lower. The left lane saturation flow showed 12.5 % higher, whilst the right lane revealed 10 % lower. In general, however, saturation flows of the left lane are not always smaller than for the middle lane. This is not in line with the expectation that saturation flow on the near side lane is usually smaller than offside lane.

Statistical tests were performed to examine the difference between the normal saturation flow (without a blockage) and saturation flow from each blockage distance, the F-test and t-test were used. Furthermore, the tests were also carried out to examine the difference between mean saturation flows from the contiguous blockage distances. The results showed that from all blockage distances mean saturation flows confirmed a significant difference from normal at 95 % confidence level. Moreover, a comparison of saturation flow between contiguous blockage distances showed that means of saturation flow were significantly different for every pair of contiguous blockage distances. It is interesting to mention that any saturation flow from the right hand lane was no significant difference from the normal. It suggests the presence of a parked vehicle on the left hand lane had no effect on saturation flow of the right hand lane. Whilst, saturation flows of the middle lane, not surprisingly, showed their significant difference, except for the blockage distance of 75 m.

To analyse the reduction of saturation flow due to the parked vehicle in compatible with the current method of saturation flow prediction (Kimber et al, 1986), the reduction of saturation flow was considered on the lane by lane basis. To develop the relationship, blockage distance was taken as the predictor variable whilst mean reduction of saturation flow was taken as the dependent variable. A curve fitting method in SPSS-Windows was used to build the regression models on the mentioned variables.

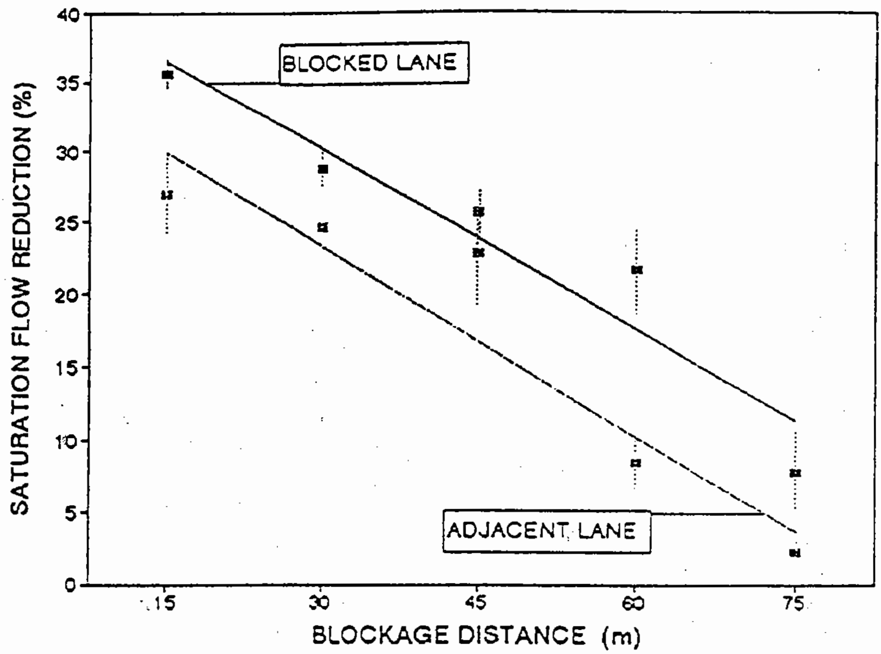

Figure 1. The relationship between saturation flow reduction and blockage distances (Bars represent ± one standard error)

It was found that the relationship between mean saturation flows and blockage distances was linear and can be expressed in the equations, as follows :

For the blocked lane :

$$Y = -0.419 X + 42.728, \quad r^2 = 0.916 \quad 15 \leq X \leq 75 \qquad (1)$$

For the adjacent lane :

$$Y = -0.436 X + 36.810, \quad r^2 = 0.899 \quad 15 \leq X \leq 75 \qquad (2)$$

where for both cases :

Y = saturation flow reduction (%)

X = blockage distance (m).

Figure 1 depicts the plot of these relationships. Obviously, saturation flow reduction on the blocked lane is always greater than on the adjacent lane. This is because the effect of a parked vehicle is larger on the blocked lane rather than in the adjacent lane. Therefore, there is a strong evidence that saturation flow is much influenced by diverging vehicles in front of the parked vehicle; lane changing from the adjacent lane to the blocked lane, results in larger discharged headways

The limitation of this model, however, is the exclusion of the green time variable which may increase the accuracy of the formulae, as described by Webster and Cobbe (1966), Akcelik (1981). The exclusion of this variable was caused by inability to collect data for different signal settings. Note that the model may well be still valid for another locations, since data was collected on the conditions of a green ratio around 0.5 which is commonly used in practice.

Extra delay

As mentioned previously, the presence of a parked vehicle causes an extra delay. The extra delay is derived as the difference of travel time between two conditions; with and without a blockage. Results from the analysis of the observed travel times can be presented in Table II along with the original and truncated data.

Table II. Travel time in minutes

Blockage distances	Original data				Truncated data			
(m)	Median	Mean	n	Sd	Median	Mean	n	Sd
15	2.30	2.53	172	0.97	2.07	2.19	137	0.69
30	2.07	2.18	307	0.90	1.77	1.90	241	0.60
45	1.70	1.78	201	0.86	1.65	1.66	156	0.30
60	1.44	1.49	334	0.44	1.47	1.44	215	0.11
75	1.34	1.71	345	0.66	1.38	1.31	224	0.39
NV	1.30	1.19	240	0.52	1.09	1.09	169	0.21

Based on Table II extra delay can be calculated and the results are presented in Table III. The observed extra delay shows that the smaller the blockage distance the larger the extra delay and may well cause a worse level of service. Observed extra delay showed that there is a strong evidence of the linear relationship between extra delay and blockage distance

Table III . Mean extra delay due to the parked vehicle

Blockage distance (m) :	15	30	45	60	75
Extra delay (sec/veh) :	60	48.6	34.2	21	13.2

Hence, from data collected during the field experiment, mean extra delay was regressed against blockage distance and the result can be presented with the equation (3) and depicted in Figure 2.

$$Y = -0.89\ X + 76.56; \quad r^2 = 0.983; \quad 15 \le X \le 75 \qquad (3)$$

where:

Y = extra delay due to the parked vehicle (sec)

X = blockage distance (m)

As extra delay may well be sensitive to flow, therefore formula (3) holds true only for a certain flow as when data was collected.

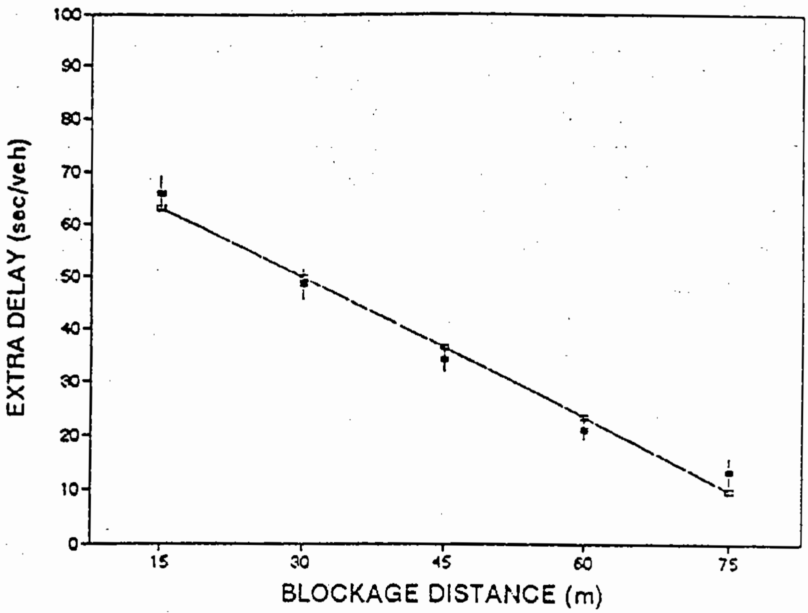

Figure 2. Relationship between observed mean extra delay and blockage distance (Bars represent ± one standard error)