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Traffic data logging system for red-running violation studies

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INTRODUCTION

Video cameras, which are relatively portable and can be deployed at short notice with minimal costs, are conventionally used for red running violation studies at signalised junctions. However, Lee and Tham (1996) and Wee and Yeo (1996) had revealed a number of limitations associated with the use of video cameras under Singapore’s environment. It was found difficult to position the camera for a good view of the junction approach including signal lights, and yet remaining inconspicuous to approaching drivers. Presence of field enumerators attending to the video cameras also impinged upon drivers’ attention that might thus affect their behaviour. Data reduction from video footage was very tedious and labour-intensive. For example, it was found that, on average, every hour of video filming on a three-lane approach required approximately 9 man-hours (3 hours per lane) of data reduction. Lighting and manpower requirements also limited video-filming applications to regular daylight hours. Large vehicles (buses and container trucks) in the near view tended to obscure smaller vehicles in the background. It was also extremely difficult to correctly obtain the times of vehicles passing over the stop-line during the signal change interval. To a certain extent, frame-by-frame viewing during video playback may help to resolve this complication, as each film advances by 0.04 seconds.

With such problems faced in video-based data collection at signalised junctions, it is evident that the use of a traffic data logging system is a practical alternative. Traffic data loggers that are widely used nowadays are typically configured to collect traffic volume, vehicle length and speed under moving traffic conditions along a road segment. Data logger used at road junctions will require more advanced capabilities to cater for moving as well as stationary vehicles. The data logger should preferably be capable of registering the time event of signal phase-change at signalised junctions. This would enable the traffic passing over the stop-line to be grouped under the green, amber and red phases. In addition, the time at which the front of a vehicle passes over the stop-line must be accurately resolved to within one-tenth of a second or better. Statistics such as amber and red violations, on a per lane basis can then be accurately determined. Unfortunately, conventional traffic data loggers are not designed for such sophisticated junction studies. These constraints had thus provided the impetus to search for a comprehensive data logging system.

Technical requirements of data logging system for junction studies

There are many aspects of the technical requirements pertaining to the design of a dedicated traffic data logger. In the following discussion, the operational aspects and memory constraints which are considered to be of prime importance for traffic studies at signalised junctions are elaborated.

Operational Aspects

The logger is to be designed to log the timing of the change in signal phase for the approach being monitored. The phase-change timing can be established using suitable cold contact connections between logger and traffic signal controller via an interface box with relay systems.

Vehicle detection can be based on the inductance loop and/or piezo sensors buried in the road pavement. Piezo detectors have the advantage of requiring less space and thus can facilitate the installation of sensors after the stop-line where limited space is available. This is critical at junctions.
approaches where the desired clear space is already taken up by red light camera (RLC) loops.

Another operational consideration is the number of input channels to be provided by the data logger whereby one input channel each is needed for the recording of traffic data from each loop sensor. As each lane provides the opportunity to violate the red signals, it is desirable to capture the traffic data on an individual lane basis. For each lane, two loop sensors should preferably be used for data collection, one placed before and one placed after the stop-line referred hereinafter as ‘before’ and ‘after’ sensors, respectively. The ‘before’ sensor acts as a detection zone to gather information on the opportunities presented to vehicles to stop or violate the red signal, and can be used to track vehicles who have the opportunity to violate the red signal but choose to stop. The ‘after’ sensor serves to collect information on the amber crossing and red-light running characteristics. Having two sensors near the stop-line serves to counter-check as well as eliminate unwanted detection signals that were picked up by one sensor alone. From these deliberations, one can infer that 8 channels would be needed to simultaneously record traffic data up to a maximum of 4 unidirectional traffic lanes.

In operation, the logger should record with high time resolution the time tag of the ‘loop on’ and ‘loop off’ events of each individual vehicle passing over the respective loop sensors. The on-load and off-load detection timings are necessary for the calculation of, among many others, speed and violation times. Besides logging individual vehicle data, the logger should also be capable of accumulating vehicle counts on a lane-by-lane basis as per signal phase (Green, Amber and Red).

Stop-and-go action is quite common at signalised junctions, especially during periods of heavy congestion. The data logger should be designed to ‘hold’ the presence detection of a stationary vehicle for a certain period of time, say, preferably longer than the largest practical signal cycle of 2 to 3 minutes. A ‘hold’ time of 3 minutes was chosen as the threshold, after which the logger re-tumes and ‘loses’ the vehicle.

Memory Constraints

In view of the numerous data to be logged, provision of a large non-volatile memory in the data logger is an important consideration. The required memory size is directly dependent upon the number of loop sensors or input channels connected to the data logger. Traffic volumes and, to a lesser extent, the number of signal cycles also affect memory requirements. It was estimated that 6 bytes of memory space are needed to record the timing and status of each loop sensor (‘loop on’ or ‘loop off’). An additional 6 bytes are required to store the timing and status of the signal phase-change event. Based on the maximum size of 2-Megabyte memory card available in the market at the time, one can record up to slightly more than 330,000 vehicles and/or signal phase-change events. With all eight channels in operation, each loop is calculated to record, on average, the passage of 20,000 vehicles. This was found to be more than sufficient to store a full day’s data. Hence, for all practical purposes, a 2-Megabyte memory size would enable downloading or data retrieving on site to be carried out at intervals not shorter than a full day.

Marksmann 660 as the traffic data logger

Based on the functional requirements of the data logger as discussed in the earlier section, a number of traffic monitoring devices were evaluated and found not to comply fully with specifications. Hence, the choice of custom-build to specifications versus custom-modified of an off-the-shelf data logger was evaluated. Further considerations indicate that custom-modified option appeared to be more suitable due to time constraints and funding problems in this re-

search study. It was found that an existing off-the-shelf traffic data logger developed by Golden River (1996), the Marksmann 660 or commonly known as M660, offers the greatest potential to be used for traffic studies at signalised junctions. However, modifications on the hardware as well as the software aspects of the M660 are necessary for it to fully fulfill the desired functional requirements. The M660, as shown in Figure 1, was custom-modified to take inputs from a traffic light controller defining the status and time occurrence of the traffic signals. This is handled by using a traffic light controller interface that sits in-between the signal controller and the M660. The change in signal phasing in sequence of green, amber and red of each approach is constantly monitored using relays, one for each signal phase. The exact instant and status of the signal phase change are transmitted to the M660 via the traffic light controller interface (see Figure 2 for connection details). In essence, the 8-channel M660 includes the following basic functions:

- Vehicles are detected via inductance loop and/or piezo sensors buried in the road.
- Changes of signal phase, indicated to the logger by the traffic controller, are detected.
- The logger records the time, to within one-hundredth of a second resolution, at which signal phase changes begin, and the new state of the signal, and
- The logger logs per traffic phase per loop, up to a maximum of 8 loops, or 4 traffic lanes (2 loops per lane), and also records time-tagged sensor ‘on’ and ‘off’ events, also to within one-hundredth of a second resolution for each loop sensor.

Problems and Limitations

One would normally draw up the design specifications for the data logger to meet the intended functions and purposes in the beginning of the project. This would involve identifying all potential problems and associated solutions. It is inevitable that some complications would not be foreseen, thus, one should conduct field trials to verify the performance of the equipment and address any deficiencies accordingly.

A major operational complication involves the high frequency of starting and stopping actions of queuing vehicles at junction approach that may cause difficulty in correctly identifying the ‘on’ and ‘off’ events of each individual vehicle, as well as the accumulation of vehicle counts at each sensor. For instance, a trailing vehicle may enter the detection zone even before the front vehicle leaves, or ‘loop off’, the detection zone. This means that there would not be a significant change in the loop impedance because inductive loops
cycles tend to travel along the lane demarcation lines between queuing vehicles at junction approach. One may overcome this problem, to a certain extent, by having appropriate loop impedance and configuration to enhance the detection of motorcycles, but this would result in a higher level of cross talk. With these considerations, 1.5m long by 2.0m wide rectangular loop consisting of 4 turns of inductance wires was generally chosen as the sensor configuration for data collection.

Validation study of the M660 data logger

Validation of the data logger is essential for ascertaining the performance of the data logger and the loop sensors as an integrated system. This would help to provide an objective measure on the capabilities and the limitations of the logging system in vehicle detection at signalised junctions. Knowing the basis for the occurrences of such problems can, in turn, serve as a reference guide in the data interrogation stage as discussed earlier. For instance, when should it be considered as a vehicle detection or ‘noise’ being recorded by the logger? If the dwell time (the time difference between ‘loop off’ and ‘loop on’ events) is less than, say, 0.1 seconds, one can confidently infer that it must be due to ‘noise’ and not by vehicle actuation. As a result, one would be able to interpret the results more meaningfully. The purpose of validation study is, therefore, to provide details and confirmation on the correct setting of M660, appropriate loop impedance and configuration, and sufficient clearance distance between any two closely placed sensors. Hence, the scope of validation would, among other things, include the ability of the loop sensors to detect various vehicle types under all possible traffic flow conditions such as congested as well as non-congested periods. Also, to be able to identify problems associated with the magnitude and causes of under- or over-detection by the loop sensors for vehicle types. One obvious way to validate M660 is via video filming concurrently with M660 in operation. The logger data would then be compared with the video data to check for any inconsistencies in vehicle detection by the sensors. With a good pictorial view capturing the happenings at the junction entrance, the video recording would help to provide essential details on what actually went wrong with the logger as well as the circumstances leading to such errors.

Validation Results and Analysis

The validation study showed a rather high detection rate of about 95%. The data logging system could have performed better if not for the under-counting of motorcycles, which were detected at an average detection rate of about 64%. Problems, which affected about 5% of all vehicles passing over the loop sensors, that are commonly associated with inductance loop sensor for data collection are shown in Figure 3. The findings indicate that motorcycles escaping detection (47%) is the main cause of under-counting. This is followed by ‘cross talk’ at 21%, and then by ‘noise’ at 16%. Lane changing at stop-line and ‘others’ each contributes 8% to the causes of problems.

RED-RUNNING VIOLATION STUDIES AT BEFORE-AND-AFTER JUNCTION

The case study, which is used to demonstrate the feasibility of using the data logging system for junction studies, focused on evaluating the impacts of RLC on red-running violation rates and their after-red times. Field data such as, among others, volume and red-running violations were collected along the camera-designate approach of a T-junction, hereafter
known as the Clementi junction (see Figure 4 for details on junction layout and loop sensor placement), in the before- and after-RLC implementation periods.

Red-Running Violation Rates
A red running event is operationally defined as any occurrence in which the front of a crossing vehicle passes over the demarcated stop-line of a signalised junction after the onset of the red signal indication. Using this definition, the red violation rates were gathered for the camera-designate approach for both the before- and after-RLC periods. These red violation rates were normalised with respect to per day basis as well as with respect to per lane-volume per cycle basis (enclosed in parentheses as shown in Table 1).

A substantial drop in the number of violations per day can be observed at camera-designate approach of Clementi junction. The same pattern was observed when the violations were expressed in terms of violation rates. The reduction in violation rates at the camera-designate approach ranged from as low as 33% [2.42% / 2.128] along the kerb lane to a high of about 51% along the median lane. It was also observed, as a result, that the violation rates of the median lanes were substantially higher than the other lanes before RLC installation. However, after RLC implementation, the violation rates were still higher albeit to a very much lesser extent. The weekend (Saturdays and Sundays) violation rates were consistently much higher than for weekdays.

Violation Histograms with After-Red Times
Red running violations and their corresponding after-red times were used to generate the histogram for analysis. Time into red, or generally referred to as after-red times in this research study, is defined as the time between the output of the red signal (registered by the M660 data logger) and the moment the front of the vehicle crossed the stop-line. The violation histograms with respect to after-red times are shown in Figure 5 and are also tabulated in Table 2. It was found that the RLC had a great impact in increasing the share of violations of those having after-red times less than half a second, an increase of 13%, and corresponding reductions in the late violations. Hence, one may infer that the RLC might have encouraged early violators to speed up and clear the camera junction more speedily.

CONCLUSIONS
Within the context of the experimental setup, the validation results indicate that the data logger system is functioning efficiently within acceptable limits. The findings from the case study on the impacts of RLC clearly demonstrated that the use of a dedicated data logging system in conjunction with loop sensors provides a viable alternative to the traditional use of video cameras in field evaluative studies at signalised junctions. For example, as red running violations are rather rare events in the case study on the effects of RLC implementation, automatic logging over an extended period of time helps to gather a sufficiently large amount of data for numerical stability in the analyses. With versatility in the data collected by an automatic logging system, one can also carry out more vigorous analysis, which would otherwise not be possible with data collected using video cameras.

REFERENCES

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