DETECTING & CORRECTING PARTIAL DETECTOR FAILURE IN STRATIFIED ZONE METERING

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ABSTRACT- Stratified Zone metering is one of the coordinated ramp metering algorithm. The only input to this algorithm is vehicles per hour, where vehicles are detected by inductive loop detectors. Detectors can partially fail in special cases leading to false input and hence, wrong output given by ramp metering algorithm. In this paper we suggest how to detect partial failure of detectors and temporarily correct it.

1. INTRODUCTION

Ramp metering is the use of traffic signals at freeway on-ramps to control the rate of vehicles entering the freeway. Principal causes of freeway congestion are bottlenecks, entering demand that exceeds exiting demand and mainline flow disrupted by platoon entering demand. By regulating ramp access to the mainline, on-ramp metering aims to reduce these operational problems. [1]

System-Wide Traffic Responsive ramp metering operation seeks to optimize a multiple-ramp section of highway, often with the control of a bottleneck as the ultimate goal [2]. Typically a centralized computer supervises numerous ramps and implements control features which override local metering instructions. This centralized configuration allows the metering rate at any ramp to be influenced by conditions at other locations within the network. In addition to recurring congestion, system wide ramp metering can also manage freeway incidents, with more restrictive metering upstream and less restrictive metering downstream of the incident.

2. PRELIMINARIES

2.1 Algorithm

Stratified Zone metering algorithm is one of the system wide traffic responsive ramp metering algorithm and its objective is to delay the onset of congestion for as long as possible, while restricting meter wait times to no more than 4 minutes (2 minutes for freeway-to-freeway meters).

The ZONE metering algorithm [3] is built on the basic philosophy of balancing the volumes entering and leaving the zone. It is implicitly assumed that when the total volumes entering and departing are balanced, variations of zone density are maintained within a narrow range; thereby flow is smoothed out and the level of service is improved as compared to the “No Control” alternative. This philosophy is expressed in the zone conservation equation:

$$M \le X+B+S-(A+U) \qquad (1)$$

M represents the number of vehicles entering through ramp;

A represents the measured upstream mainline volume;
U represents the total measured non-metered ramp volume;
X represents the total exit ramp volumes;
B represents the downstream bottleneck capacity;
S represents the spare capacity the space available within the zone.

2.2 Inductive Loop Detector

In order to get the values of number of vehicles at different sections Inductive loop detectors are used which can be placed in a roadbed to detect vehicles as they pass over the loop by measuring the vehicle's magnetic field. The simplest detectors count the number of vehicles during a unit of time that pass over the loop [4]. Loops can be placed in a single lane or across multiple lanes, and they work with very slow or stopped vehicles as well as vehicles moving at high-speed. An inductive loop vehicle detector system consists of three components: a loop (preformed or saw-cut), loop extension cable and a detector. When installing or repairing an inductive loop system the smallest detail can mean the difference between reliable detection and an intermittent detection of vehicles.

When a large metal object, such as a vehicle, moves over the loop, the resonate frequency increases. This increase in frequency is sensed and, depending on the design of the detector, forces a normally open relay to close. The relay will remain closed until the vehicle leaves the loop and the frequency returns to the base level. The relay can trigger any number of devices such as an audio intercom system, a gate, a traffic light, etc. In general, a compact car will cause a greater increase in frequency than a full size car or truck. This occurs because the metal surfaces on the under carriage of the vehicle are closer to the loop.

2.3 Problem

There is a misconception that inductive loop vehicle detection is based on metal mass. This is simply not true. Detection is based on metal surface area, otherwise known as skin effect. The greater the surface area of metal in the same plane as the loop, the greater the increase in frequency. For example, a one square foot piece of sheet metal positioned in the same plane of the loop has the same effect as a hunk of metal one foot square and one foot thick. Another way to illustrate the point is to take the same one square foot piece of sheet metal, which is easily detected when held in the same plane as the loop, and turn it perpendicular to the loop and it becomes impossible to detect.

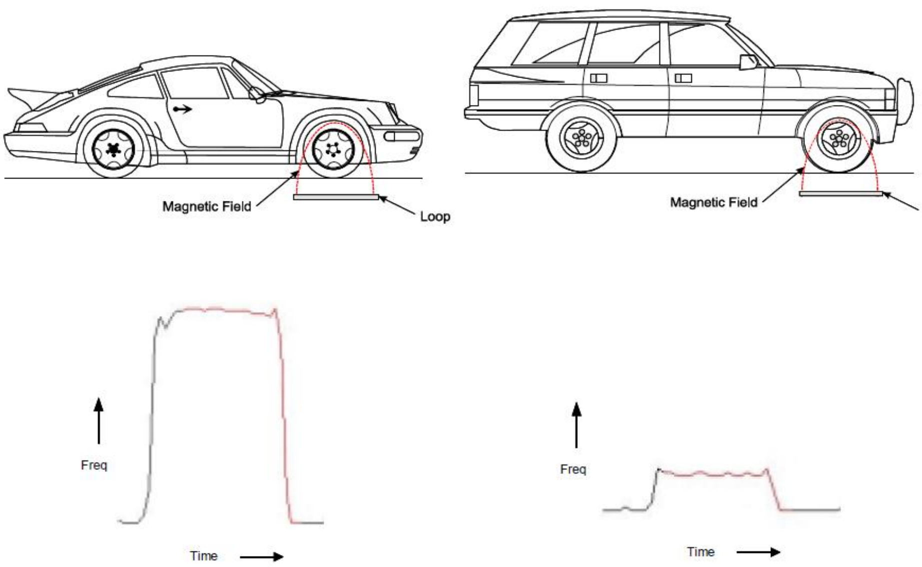

Figure 1. Effect of ground clearance of vehicles on performance of Inductive loop detector

In recent years, there has been an increase in the number of missed and false detections due to the popularity of SUV's (Sports Utility Vehicle). The missed detections can be attributed to vehicles where the metal surface area farther away from the loop which makes the vehicle which makes detection of vehicle almost impossible [5]. Figure 1 shows that change in frequency of detector is different as ground clearance of vehicles is different. Hence, if ground clearance is higher of particular vehicle, the frequency change is lower. The positioning of detectors plays an important role in correct detection. The only input to the algorithm is number of vehicles per hour passing through different segments, this input needs to be checked for correct values. There is no proposition in original algorithm of stratified zone metering to check the validity of input given by different detectors, we propose an improvement in algorithm by detecting and correcting partial failures in detectors.

3. PROPOSED IMPROVEMENT IN ALGORITHM

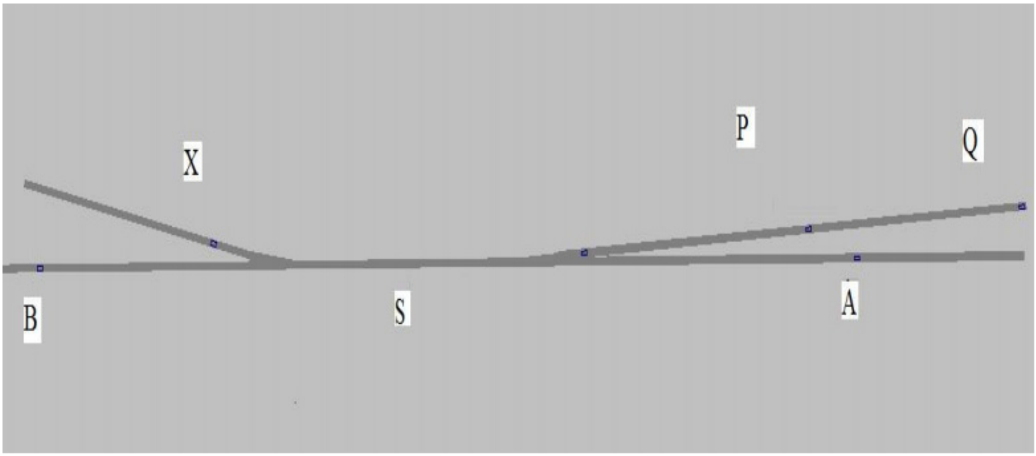

Figure 2: Layout of detectors

In Figure 2, the layout of detectors are shown, 'A' is upstream traffic detector, 'Q' is queue detector for ramp, 'P' is passage detector, 'S' is spare detector to find out mainline traffic, 'X' is to calculate number of vehicles that are exiting from mainline traffic, 'B' is downstream traffic detector.

The values collected from detectors are collected for 30 minutes where the values can then be judged if the detector is working properly or if there are significant drops in their value as the value given by detectors can only be less than the actual value of vehicles that passed over detectors.

We start with P (Passage detector) and Q (Queue detector) here there can be three different cases, P and Q can rely on each other as Q/P = 1.1,

1) P is working and Q is not working, Here Q's Value will have deviation and hence, the Q/P ratio will be less than 1.1 and then we adjust the value of Q by using the P's Value.

2) P is not working and Q is working, Here P's Value will have deviation and hence, the Q/P ratio will be more than 1.1 and then we adjust the value of P by using the Q's Value.

3) P is not working & Q is not working, Both are not working then condition can be either when value of P > Q or Q > P. The condition where P > Q is easily detected because then Q/P ratio will be even less than one, but if the condition is where Q>P and ratio of Q/P is still 1.1 then it's impossible to detect if the detectors are working properly or not, in other conditions it will be easy to solve the problem.

• If U (non-metered detector) fails partially then its value won't cause a problem or in other words it's insignificant.

•B (Downstream detector) and X (Exit detector) will rely on each other, depending on its historical data and approximation we can tell if one of them is working properly or not and the ratio of B/X taken in our proposed solution is an approximately ranging from 5 to 15, since the traffic flow is in manner that this range is perfect.

If the ratio is less than 5 or more than 15 then change is quite significant and then the values of B and X are changed.

If ratio < 5 that means B is not functioning properly and it's giving incorrect values then we can approximate value of B as 10 times the value of X.

If ratio is > 15 that means X is not functioning properly and it is giving incorrect values then we can approximate value of X as 0.1 times the value of B. If both fail we can use previous detector because it will be equal to sum of B+X.

• S (Spare detector) value can be checked by depending on both values of X and B, since B + X = S, hence S can be checked for partial failure through this method.

4. RESULT

The proposition was implemented and tested using VisSim (Visual Simulator) and the scripts were written in Visual Basic. The map on which it was implemented is shown below (figure 3),

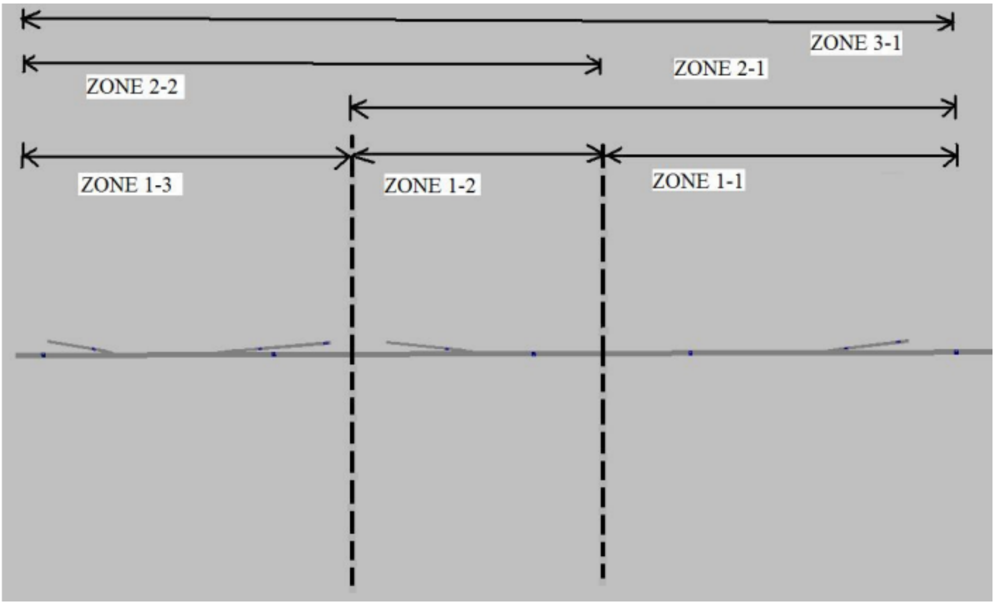

Figure 3: Map on which the test were conducted

In Figure 3, Input vehicles come from right to left and the vehicle input is approximately 1500 VPH (Vehicles per Hour) and for both the entry ramp the inputs is 400 VPH and through exit ramps around 400 VPH exit is taken into consideration. Now the Partial detector failure was also taken into consideration and the code was written in that respect. As expected the results were very promising over the Stratified Zone Metering algorithm with partial detector failure. Results are shown in Figure 4.

In this figure X axis shows time in minutes where data was gathered in every 3 minutes and Y axis shows travel time in seconds. From figure it is evident that SZM efficiency decreases in first 30 minutes as due to false reading the result from algorithm can be very varying. But after 30 minutes the algorithm stabilizes as after then it's understood that there is partial failure and approximation is used to make the algorithm again effective.

5. CONCLUSION

In this paper we conclude that this improvement is effective, as Stratified Zone Metering algorithm can produce erratic results if the detectors give wrong input attributed to factors stated in previous chapters. Improved algorithm takes into account the cases where detectors can partially fail and provide wrong input. It not only detects these cases but also substitutes the appropriate values, so that algorithm could still function and on notification from this system, detectors can be checked for possible failures by appropriate traffic department.

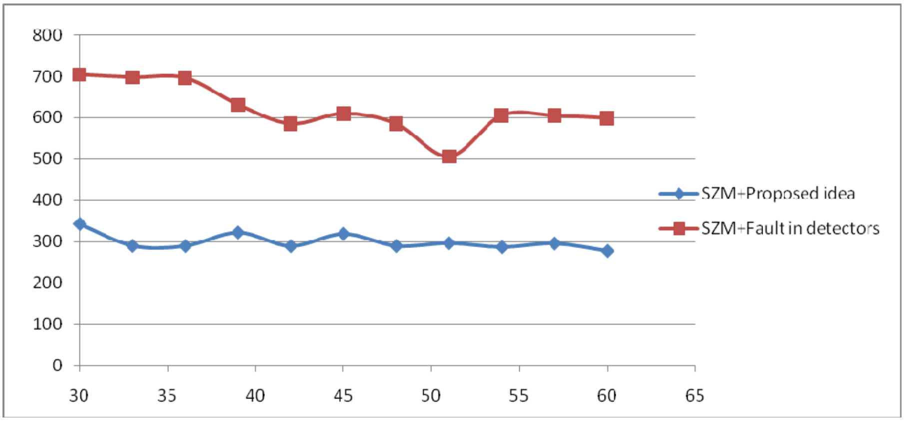

Figure 4: Result Showing that Proposed Solution works better

(SZM: Stratified Zone metering algorithm)

6. ACKNOWLEDGMENT

I would like to thank my guide Dr. Joseph Mouzna, Dr. Tahar Berradia and Mr. Quoc Chuyen Doan at ESIGELEC, without their guidance this research work wouldn't have taken right direction. The work was carried out at IRSEEM Labs, ESIGELEC, Rouen, France.

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