Data Combination from Probe Car and Partial Video Data to Estimate the Traffic State

by Mustafizur RAHAMAN* , Hisashi KUBOTA**

1. Introduction

For pre-trip route planning and guiding the travelers accurately the function of the advanced traveler information system (ATIS) is to provide accurate traffic information. The commonly used quantitative traffic measures are travel time, speed, delay, volume, density, and level of service (LOS).Although among them in general travel time and speed, delay these are readily perceived and understood measure indices for the travelers. The efficiency of the roadway network can be improved and lower-level pollutant emissions and a safer driving environment be realized by applying different TDM (traffic Demand Management) technique to reduce the prevailing congestion prior to which estimating the prevailing travel speed and the travel time, delay, flow rate and density of the links in the network which indirectly indicates the congestion situation of the road is also a major issue to be taken into account.

Originating from optical engineering and electrical engineering, data combination or fusion from multiple data sources have been using particularly in the fields of traffic operation and control, traffic and incident management, and intelligent transportation systems (ITS). The ability of providing richer information from multiple data sources, it has the advantages of providing higher reliability, robustness and credibility, faster and more accurate estimation and prediction, and broader spatial and temporal coverage in many traffic management and control applications and for this reason data fusion technique from two or multiple sources has drawn the attraction of the transportation researchers.

The existing travel time or journey speed estimation techniques are based on either aggregate point-based traffic measures, i.e., volume, occupancy, spot speed and so on or individual section-based traffic measures, i.e., travel times of individual probe vehicles. The point-based traffic data are readily available from the widely installed inductive loop detectors (ILD) and other loop emulators such as magnetic, ultrasonic, infrared, microwave detectors and etc., while the section-based traffic data can be obtained using automatic vehicle location (AVL) technology such as global positioning systems (GPS) and cellular phone tracking, and automatic vehicle identification (AVI) technology including the existing electronic toll collection (ETC) systems, the emerging video and machine vision based license plate reader (LPR) systems and video image tracking system, and the being-developed vehicle signature re-identification techniques based on a pair of Inductive Loop Detectors.

Here a data combination method has been proposed to estimate the road traffic condition to evaluate the prevailing traffic state and congestion situation based on the traffic engineering principal. Here data from the two sources are combined to develop the vehicle trajectory for each and every vehicle in the desired link and graphically show the speed and the congestion situation and delay by the color code in relation with the speed developed by the observation method. These two data sources are probe car data and video data which provide partial spatial coverage of the designated link it is covering.

2. Background and literature review

Use of individual section-based travel time measures has a higher spatial and temporal coverage and provide rich information of the existing traffic condition including the travel time and delay. This type of methods, however, depends on the penetration rate of equipped or captured probe vehicles in the network. On the link level, a number of individual probe vehicle travel times may be required during a time interval to give a sufficiently accurate estimation of the true average travel time and traffic state, due to the dynamic and stochastic attributes of the individual vehicles and interruption of flow for different external and internal factors. On the other hand the fixed sensor based travel time provides the higher temporal coverage but suffers from some drawbacks like on-link point traffic measures may only reflect the traffic conditions in the vicinity of the sensors and hence are quite difficult to represent traffic variations along the whole link and is affected by many factors, including dynamic factors as traffic demand, vehicle composition, traffic control, pedestrian crossing, bus stopping and etc.. An arterial link travel time estimation model using point traffic measures may not effectively encompass or interpret all the dynamic and static factors. Figure 1 shows the sampling of the probe car for the one hour taken from the test bed Kawagoe. It shows that the probe car provides richer information about the prevailing road traffic condition as it is used to plot time space diagram but due to the inadequate frequency it cannot provide the actual situation of the road during the gap period between the probe vehicles. Figure 2 shows the drawback of the sectional video data as it can provide a good temporal coverage of the portion but fail to cover the entire link due to some physical barrier. Thus cannot support the analysis of the traffic parameters alone.

Key Words: Data fusion, Probe data, Time Space Diagram, Traffic Demand Management, Intelligent Transportation Systems(ITS).

* Master course student, Urban Planning and Design Laboratory, Graduate School of Science and Engineering, Saitama University (Urban Transportation Group, Graduate School of Science and Engineering,〒338-8570,255 Shimo-Okubo, Sakura-ku, Saitama, Japan ; Telephone-090-9853-4393; Email: rahaman@dp.civil.saitama-u.ac.jp, mustly2060@yahoo.com)

** Professor, Dr. Eng., Urban Planning and Design Laboratory, Graduate School of Science and Engineering, Saitama University

Existing data fusion techniques are mainly based on the statistical concept and probabilistic approach and do not benefit from the principles of traffic engineering. They normally used the weighted combination of travel time from different sources but the delay due to the fixed traffic signal at the intersection and delay due to the various factors and facilities in urban roads are not considered.

Berka et al. (3) proposed data fusion method in ADVANCE, weighted averaging, which is analogous to the virtual sampling method. This approach was applied to data fusion of probe vehicle and fixed detector travel time estimates, where Westman et al. (5) explored the integration of probe vehicle and loop detector data for travel time estimation and incident detection and Thomas (9) proposed several multi-state multi-sensor data fusion models for arterial incident detection. Probe vehicle travel times, number of probe vehicle reports, and detector occupancy and volume as inputs are combined. Bayesian score rule is applied to detect incidents as making a multiple attribute decision. Klein et al. (10) introduced and tested the Dempster-Shafer theory for data fusion in support of advanced traffic management. Dempster-Shafer inference is a statistical data classification technique for detecting and identifying traffic events that affect normal traffic operations. It can deal with the conditions in which data sources provide discontinuous and incomplete information, and no single data source can produce a high probability of certainty for identifying the most probable event. The algorithm captures and combines any certainty existing in the object discrimination or event classification capability of the sensors and other information, as contributed by the data sources using Dempster's rule. The potential

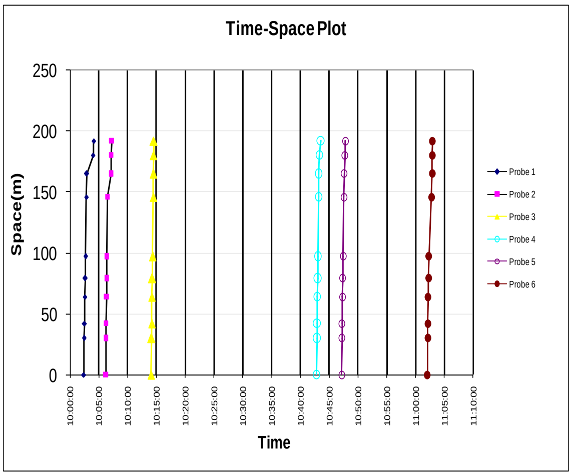

Figure 1: Frequency of the Probe car for one hour Sampling

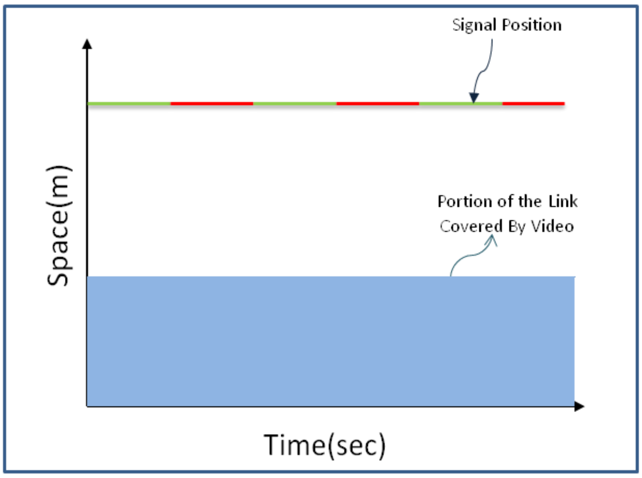

Figure 2: Limitation of the data only from the Video

application of Dempster-Shafer Inference in traffic parameter or variable estimation may need further investigation. Berkow et al. (11) recently used the graphical method to fuse the data from the loop detectors data and the transit bus probe as sectional data. Specially, the two sources data were collected at the same time simultaneously by taking the consideration of the transition of the traffic state which was absent in the previous works of data fusion. But using the transit vehicle as probe has several drawbacks like stopping due to passenger serving and may provide flawed result and they also did not take into account the delay due to traffic signal at the intersection.

With a view to find the travel time and journey speed measurements accurately this paper proposes a where data from the probe car along with the video data to produce the time space diagram of the whole sampling period .The delay due to the signal at the intersection has been taken into account and benefitted from the concepts of the traffic engineering.

3. Methodology

Proposed research is based on the idea of the combining the data from the two sources e.g. probe car data and video data for the estimation of the traffic state. Both running the probe car and the video recording were done simultaneously for the sampling period and for the desired links. It is obvious that penetration rate of the probe car should be the very high for observing the traffic state properly. But due to several reasons as the probe car is not sufficient over a link. On the other hand it is not possible that the whole link could be covered by the video recording of the section. Only partial section can be covered by the video as the link may be long enough and there may have some radial curvature, physical barrier on the link which is difficult for the video recorder to capture.

Now from the video recording data, the entry time and the total number of the vehicles for the desired link and desired sampling period can be attained. Moreover the portion of the link that is perceived from the video data provides with the spatial and temporal coverage. As a result the travel time for the every vehicle entering into the link up to the perceivable distance, can be extracted. And the probe data provides the temporal coverage of the link and provides the position of the car along with the time.

Now the both the data is combined with a view to find the traffic surveillance parameters like the travel time and the congestion situation and delay. Figure 3 shows the way how data form the two sources will be combined in this paper.

Suppose the total length of the link is L then the portion of the length covered by the video is x. Then the vehicle time-space diagram for the L-x distance cannot be readily constructed. So for that uncovered section (L-x distance) of the link the car following theory has been used taking the probe car as reference. If the total length of the link is broken down into several length segments like $x_1, x_2, x_3 \dots x_n$ and the travel time for the each segment for the probe car is $t_{1,}$

$t_2, t_3 \ldots t_n$ then the following car of the probe will take the same time for the same segments. In the same way following cars will pass the whole link until they are hindered by the traffic signal. In this case the car stops and starts again when the signal is green. From the starting point it again follows the path of the preceding car.

Table 1: Color Coding in relation with the speed and travel time

Color	Travel Speed(km/hr)	Travel Time(sec)
Red	0-3	230-
Pink	3-5	140-230
Yellow	5-8	87-140
Orange	8.1-14	50-87
Green	14.1-18	39-50
Deep Green	18.1-30	23-39

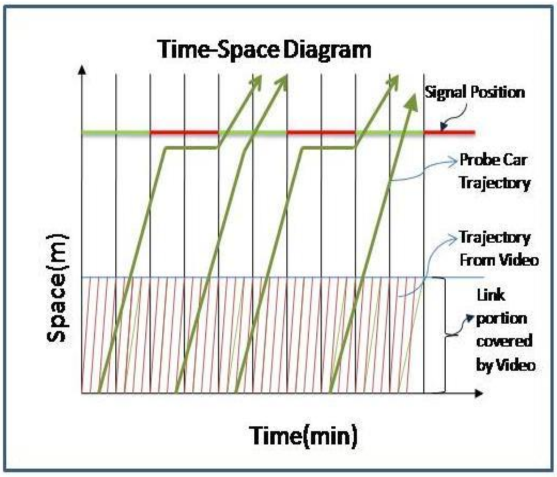

Figure 2: Initial data combination from the video and the Probe car

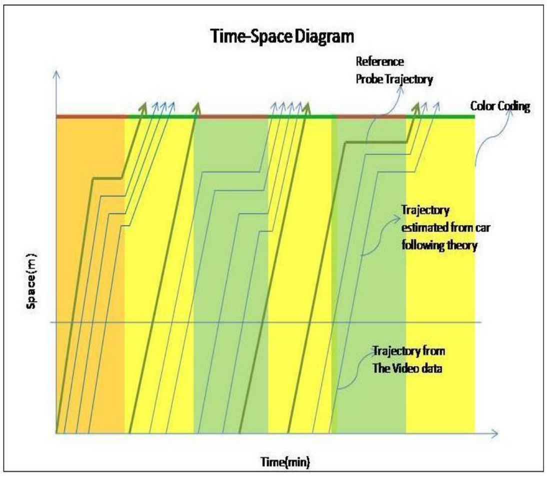

Figure 3: Data combination from the video and the Probe car and color coding

Now in this way after finding the time space diagrams for the entire link of all the vehicles that have been partially traced from the video, we can have the traffic parameters of the link revealed. In order to understand the congestion situation of the links then a color coding method is adopted. To depict graphically a color coding method was developed based on the observed speed of the probe cars and time to pass the desired links and shown in the Figure 4. Table 1 shows the speed limit and the estimated color reference for that speed. Then with the color coding developed heuristically are used to depict the speed condition of the link for the aggregation period which was chosen according to the cycle length of the signal in this paper. Then for a cycle length the number of the vehicles entered and their speeds along to the spatial coverage given by the video data are extracted. Then the average of their speed is done to show the speed of that portion of the link according to the speed limit and the color coding relation described earlier.

4. Study area and data collection

Figure 5 : Map of the whole Kawagoe area

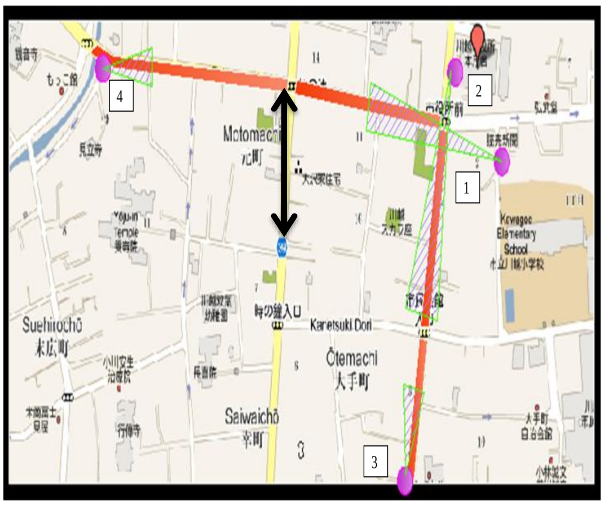

Figure 6: position of the video camera with the portion of the link covered

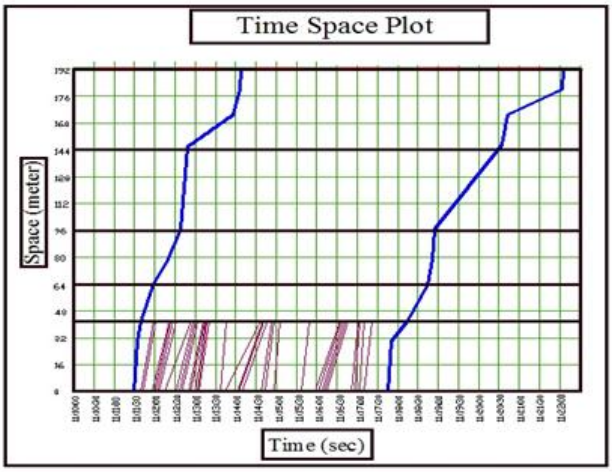

Figure 7: Probe and the Partial Video recorded data in the same Time space Plane

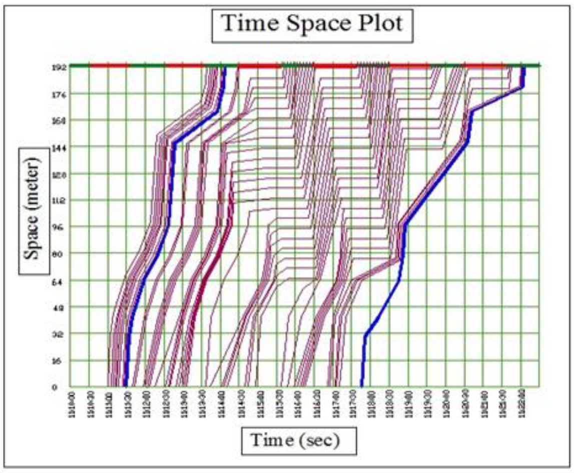

Figure 8: Estimated Trajectory of the vehicles from the video data along with the Probe data

Data used for the proposed methodology was collected from Kawagoe, a tourist prone town in Japan. It is one of Japanese historic cities located near the nation's capital, Tokyo. The old buildings, temples, and shrines offer a glimpse into old Japanese towns. In particular, Ichibangai Street is a famous historical spot, lined with traditional buildings called "Kura". The Kura is originally a building used for storage, however, Kawagoe's people have used it as a shop and a dwelling too, since they found its fire-resistance performance. The area is defined as "Important Preservation Districts for Groups of Historic Buildings" by Japanese government. The data has been collected by performing the video recording and running through the probe car along the designated links simultaneously. Video recording was done from higher position from the ground to catch up the link. But due to some physical barrier and due to camera focusing limitation for the first camera position could cover about 25 percent of the total length while the second camera position could cover about 50 percent of the focusing length of the link. The spatial coverage of the other two video cameras in the Kawagoe area have covered not more than 10 to 15 percent of the facing links.

5. Analysis and result

A sampling period of several minutes has shown in this paper from the test bed area of the Kawagoe as recorded by the video camera no. 1 and probe car. In the Figure 7, first the frequencies of the probe cars have been shown with the bold blue line. Then for the same time the recorded video data has been changed to the vehicle trajectory using the traced car travel time of the perceived portion and shown in the same figure combined together with the probe car data. Then according to the car following theory for the unknown portion of the link traveling patterns of the vehicles within this two probe vehicles about 8 minutes apart have been shown in the Figure 8.

Now the length of the link has been divided into some blocks in the horizontal axis and then in the vertical time axis it has been divided into 2 minutes block s according to the signal cycle length (Figure 9). For the each block the speed of the each vehicle is calculated and then the average speed of the each block has been calculated and then it the block has been colored according to the color coding and shown in the Figure10. Figure 11 shows the sampling of the travel time of each vehicle extracted from the estimated trajectories. If the influence of the left and the right turn vehicle at the

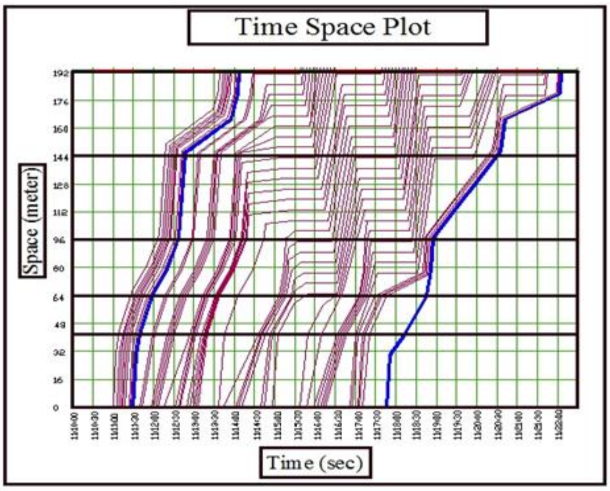

Figure 9: Horizontally divided block along the space plane in the time space diagram

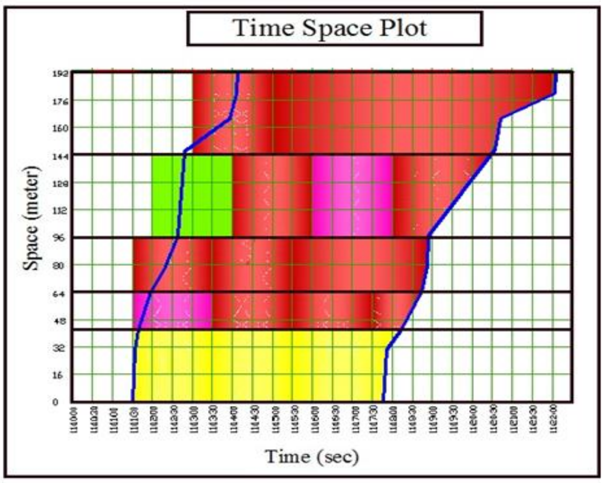

Figure 10: Using color code fill up the time space plane from the estimated trajectory between the two probe cars

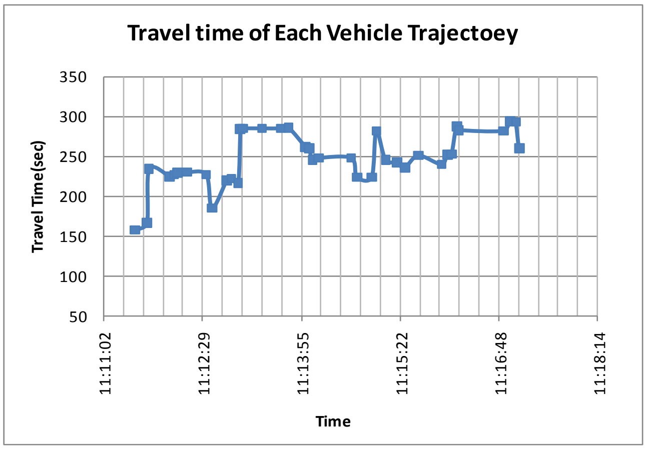

Figure 11 : Comparison of the travel time of each vehicle extracted from trajectory

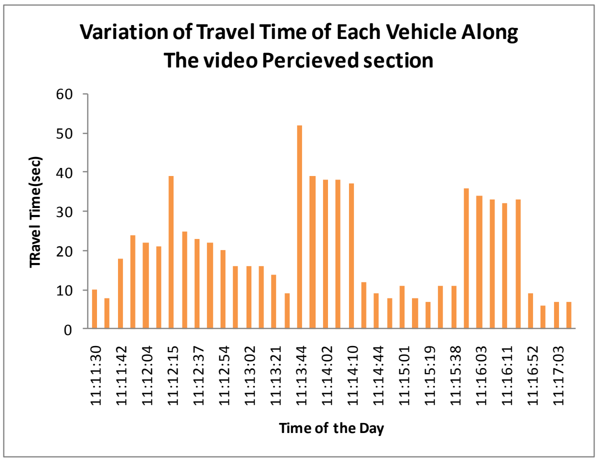

Figure 12: Travel time of each traced vehicle from the Video data along the perceived portion of the link

downstream of intersection is not taken into account, Figure 12 shows the delay at the entrance of the link due to the pedestrians walking along the road.

6. Conclusion

As a part of applying the Traffic Demand Management measurement in the Kawagoe this paper shows the result of the prevailing traffic condition in the vicinity of street where Kura Building are located. Analyzed and represented data shows that in the Holiday the road is congested and the vehicles have to wait a lot for passing the designated link. The average travel time to pass this link for this sampling period is about 247 second and travel speed is 2.80 km per hour, which reveals the higher level of congestion. If the influence of the left and the right turn vehicle at the downstream of intersection is not taken into account, Figure 12 shows the delay at the entrance of the link due to the pedestrian walking along the road which is about 10.11 second on average. The probe car data thus give us the information of the road traffic condition but with some time gap. On the other hand the video data continuously provided the time, headway of each vehicle entering and development of time space diagram upto the recording length and to find out the delay due to the pedestrians by taking the probe car cruising time as reference is possible. Thus situation of the road traffic and the level of congestion and travel time, travel speed and delay on the link can be extracted and graphically depiction of traffic state from the color coding in accordance with the proposed methodology is possible. After adopting the Traffic Demand Management measures the condition of traffic of the roads along the vicinity of the Ichibangai street should be calculated and then comparing it with the existing traffic condition considering the influence of the left and right turn vehicles at the downstream of the intersection will be the further extension of this study.

7. References

1. Washburn, S.S. and Nihan, N.L. Estimating Link Travel Time with the Mobilizer Video Image Tracking System. Journal of Transportation Engineering, Vol. 125, No. 1, 1999, pp. 15-20.
2. Rouphail, N.M., Targo, A., Nelson, P.C. and Palacharla P. *Travel Time Data Fusion in ADVANCE—a Preliminary Design Concept*. ADVANCE Working Paper Series, No. 21, University of Illinois at Chicago, Chicago, IL, 1993.
3. Berka, S., Tian, X. and Tarko, A. *Data Fusion Algorithm for ADVANCE Release 2.0*. ADVANCE Working Paper Series, No. 48, University of Illinois at Chicago, Chicago, IL, 1995.
4. Hamburger, H. Representing, Combining and Using Uncertain Estimates. Uncertainty in Artificial Intelligence, Ed. by L.N. Kanal and J.F. Lemmer, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, 1986, pp. 399-414.
5. Westman, M., Litjens, R. and Linnartz, J.-P. Integration of Probe Vehicle and Induction Loop Data—Estimation of Travel Times and Automatic Incident Detection. California PATH Research Report, UCB-ITS-PRR-96-13, Institute of Transportation Studies, University of California, Berkeley, CA, 1996.
6. Ivan, J.N., Schofer, J.L., Koppelman, F.S. and Massone, L.L.E. Real-Time Data Fusion for Arterial Street Incident Detection Using Neural Networks." In Transportation Research Record 1497, TRB, National Research Council, Washington, D.C., 1995, pp. 27-35.
7. Ivan, J.N. and Chen, S.-R. Incident Detection Using Vehicle-Based and Fixed Location Surveillance. Journal of Transportation Engineering, Vol. 123, No. 3, 1997, pp.209-214.
8. Ivan, J.N. and Sethi, V. Data Fusion of Fixed Detector and Probe Vehicle Data for Incident Detection. Computer-Aided Civil and Infrastructure Engineering, Vol. 13, No. 5, 1998, pp. 329-337.
9. Thomas, N.E. Multi-State and Multi-Sensor Incident Detection Systems for Arterial Streets. Transportation Research Part C, Vol. 6, No. 5/6, 1998, pp. 337-357.
10. Klein, L.A., Yi, P. and Teng, H. Decision Support System for Advanced Traffic Management through Data Fusion. In Transportation Research Record 1804, TRB, National Research Council, Washington, D.C., 2002, pp. 173-178.11.
11. Berkow,M.,Monsere,C.M.,Koonce,P.,Bertini,L.R.,Wolfe,M..Prototype for Data Fusion Using Stationary andMobile Data Sources for Improved Arterial Performance Measurement.Transportaiton Research Board,Washington D.C.,2009.