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REVIEW OF INCIDENT DETECTION APPLICATIONS. IMPLICATIONS FOR TRISTAR-INCYDENT DETECTION MODULE

Automated highway incident detection subsystems are integrated within advanced traffic management systems. Special algorithms process real-time traffic data flowing from highway detectors and inform the traffic control personnel of any traffic disruption that might be caused by an incident. Prompt and well managed action saves lives in situations where a single minute counts. The goal of this paper is twofold: first, to review existing traffic incident applications; and second, to outline TRISTAR-INCYDENT subsystem designed to detect traffic incidents on Gdańsk Agglomeration bypass road.

PRZEGLĄD ROZWIĄZAŃ SYSTEMÓW WYKRYWANIA ZDARZEŃ DROGOWYCH. KONCEPCJA SYSTEMU TRISTAR-INCYDENT DLA OBWODNICY TRÓJMIASTA

Wczesne wykrycie zdarzenia drogowego (wypadku lub kolizji) i natychmiastowa, sprawna akcja ratunkowa możliwa dzięki przepływowi informacji pomiędzy centrum zarządzania ruchem a służbami medycznymi w czasie rzeczywistym zwiększa szanse uratowania zdrowia a nawet życia ofiary wypadku drogowego. System automatycznego wykrywania zdarzeń drogowych jest pierwszym ogniwem współczesnych systemów reagowania na zdarzenia w ruchu drogowym stanowiącym integralną część współczesnych systemów zarządzania ruchem. Systemy automatycznego wykrywania zdarzeń drogowych wykorzystują dane spływające w czasie rzeczywistym z detektorów ruchu i następnie przetworzone przez algorytmy komputerowe informują operatora o prawdopodobieństwie wystąpienia wypadku oraz jego lokalizacji. Celem niniejszego artykułu będzie podsumowanie istniejących rozwiązań systemów wykrywania wypadków drogowych w oparciu o dostępną literaturę i publikacje. Autorzy opracowania przedstawili także zarys koncepcyjny modułu TRISTAR-INCYDENT do wykrywania zdarzeń drogowych na Obwodnicy Trójmiasta.

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1. THE IMPORTANCE OF AID SYSTEMS

Automated Incident Detection (AID) is the first step in the incident management process [8]. The concept has been around since the 1960s when loop detector occupancies greater than 40% informed the Traffic Management Center in Chicago of a high reduction in capacity and therefore the potential occurrence of a freeway incident. Incident detection, which is a process of determining the presence and location of an incident, is a two step process. First, it determines congestion from the surveillance system. Second, it distinguishes recurrent congestion from congestion caused by an incident.

Collisions account for almost one third of total daily delays on a typical U.S. motorway [6]. Timely and efficient incident management not only reduces queues and traffic related congestion but also saves lives. With the use of Poisson regression, Evanco [3] estimated the number of fatalities to be less by 11% when accident notification time was reduced by just over two minutes. This translated to 246 fewer fatalities in a year in the U.S. The report dealing with incident detection time indicated that the savings might be greater if the overall incident duration, i.e. the time interval from the moment of incident occurrence to clearance, had been reduced. It is difficult to estimate the direct benefits of ITS sub-systems because of simplifying assumptions to be made. In the City of Toronto itself an application of COMPASS Freeway Traffic Management System monitoring traffic incidents and congestion along Highway 401 has reduced the duration of incidents from occurrence to clearance from an average of 86 down to 30 minutes, and average delays by 537 vehicle hours. Displaying incidence messages has prevented 200 accidents annually resulting in $10 million savings [11], [12].

2. TRAFFIC SURVEILLANCE

Traffic surveillance is one of the key elements of incident detection responsible for measuring traffic flow characteristics and conveying the information to the Traffic Management Centre. There are a number of technologies employed, including [13]: Inductive Loop technology (active detector technology that responds to ferrous mass), Magnetometer technology (passive detector technology that responds to ferrous mass), Infrared technology (passive technology using contract in thermal radiation and active technology using reflected signals), Acoustic detection technology (passive), Ultrasonic detection technology (active - reflected signal), CCD cameras (passive detector using contrast in visible light), Doppler Radar (active detection using frequency shift of reflected signal), and Pulsed Radar (active technology that uses reflected signal). Commercially available sensor technologies have been recently summarized in a number of sources including [5], [8], and [9], which compare strengths and weaknesses of sensor technologies in light of reliability, performance under different environmental conditions, data accuracy, and real-time performance. Additionally, Klein [5] provides a summary on types of data, needed bandwidth, and costs of roadway-based sensors. As an example of a state of practice, a typical sensor installation for FTMS in Ontario's COMPASS system involves Remote Traffic Microwave Sensor (RTMS) for temporary installations and inductive loops for ultimate installations.

3. ALGORITHMS

The other key issue in incident detection is the algorithmic issue. There are a number of classification keys to group incident detection algorithms. One possible way [9] is classifying them as automatic (that automatically triggers an incident alarm) and non-automatic or driver-based procedures. Another possible classification system divides incident detection algorithms into freeway and arterial algorithms. Historically, most AID algorithms were developed for freeway application. Ozbay and Pushkin [8] introduced in their review another classification key of incident detection algorithm: point-based algorithms (discussed further) and spatial measurement-based algorithms that use video cameras and image processing techniques. Point-based algorithms that use upstream and downstream traffic measurements such as volume, speed, and occupancy could be grouped further into four sub-categories: comparative algorithms (e.g. California algorithms), time-series algorithms (i.e. statistical methods), theoretical models (e.g. McMaster algorithm), and AI models (e.g. GAID). All above algorithms have been reviewed in a number of sources, including [7], [8], [9], and recently [1]. Summary highlights are provided in the following sections.

4. EVALUATION

Three measures are usually used to evaluate the performance of incident detection algorithms: the detection rate, expressing the percent of detected incidents to the actual number of incidents, the false alarm rate, expressing percent misclassified instances, and the detection time, i.e. time needed for the algorithm to detect an incident. Summary of the evaluation results of the most commonly used algorithms is presented in Table 1.

Table 1
Summary of the evaluation results of the most commonly used algorithms [8]

Algorithm Type	Detection Rate (%)	False Alarm Rate (%)	Average Detection Time (secs)
Basic California	82	1.73	0.85
California #7	67	0.134	2.91
California #8	68	0.177	3.04
Standard Normal Deviate	92	1.3	1.1
Bayesian	100	0	3.9
Time Series (Autoregressive Integrated Moving Average)	100	1.5	0.4
Exponential Smoothing	92	1.87	0.7
Low-Pass Filter	80	0.3	4.0
Modified McMaster	68	0.0018	2.2
Multi Layer Feed Forward Neural Networks	89	0.01	0.96
Probabilistic Neural Networks	89	0.012	0.9
Fuzzy Sets	Good	Good	Up to 3 minutes quicker than conventional algorithms

The above results have also been confirmed by Carrasco and Litwin [2] in the case of two selected algorithms: the McMaster algorithm and the Artificial Neural Network with four input Perceptrons, one hidden layer with three processing elements, a TahAxon type transfer function, and supervised learning control of the back-propagation type rule. Considering overall good performance of these algorithms and competitiveness of North American incident management practices [10] the McMaster algorithm and the Artificial Neural Network algorithm became possible candidates to be employed and further tested in Poland.

5. APPLICATION IN POLAND

Efficient road incident management is an essential element of the integrated traffic safety management system. The main purpose of road incident management is to alarm emergency services and to inform travelers about the occurrence of an incident and related traffic restoration activities to bring the capacity of the affected highway to its ultimate value. The process of incident management is considered to be a key process, because it has a direct impact on travelers' safety. It consists of incident detection, incident confirmation, and then adequate actions taking. Road incidents also contribute to traffic delays, which are, again, affected by the efficiency of the incident management system.

Incident detection technologies are particularly concerned with incident detection time. Four technologies of accidents detections are considered to be used in Poland: patrol surveillance, driver-based procedures, technologies based on traffic flow parameters retrieved from loop detectors and technologies based on video image processing. In recent years traffic

control CCTV cameras were erected along highways in the Western Europe and across North America to provide traffic management centers with video coverage of strategic sections of highways. Traffic operators supplied with live image can verify the existence of an incident on a highway and take appropriate actions to manage the scene. However, this method seems to be malfunctioning in light of the growing number of CCTV cameras to be looked at. For this reason a more advanced, and therefore, more reliable automatic incident detection is required. Such a system should be considered for use in Poland.

Before planning for an ultimate solution for Poland a series of pilot studies should be conducted in order to justify the choice of the optimal solution. Fortunately, a dynamically developing ITS market, offers quite a broad selection of incident detection technologies. Based on initial reviews, e.g. [7], it is recommended to consider both traffic surveillance technologies: inductive loop detectors, and video image processing. On the application side, driver-based procedures, i.e. mobile phone based technologies, and automatic procedures, in particular point-based theoretical models and self-learning models.

6. ATMS FOR THE THREE-CITY BYPASS ROAD

The Three-City bypass road (Obwodnica Trójmiasta, OT) is considered to be the test site for a pilot project of implementation of an advanced traffic management system for the Gdańsk Agglomeration [4]. The Three-City bypass road, OT, has a bad reputation of having a high ratio of traffic incidents, both fatal and injury collisions, and non-injury collisions. Lack of efficient traffic management system costs lives and creates significant delays on one of the busiest highways in the region. The system will constitute a part of a future ATMS system in the OT corridor and will consist of the following modules:

- traffic surveillance module based on inductive loops and video image processing technology,
- incident detection module,
- Centre-to-centre communication module linking emergency, police, and fire departments, and
- travellers' information system.

Road incident management systems reduce traffic congestion, save on travel time, fuel consumption and emissions. First of all, they allow prompt incident detection and timely rescue response and site clearance. Detection time and prompt arrival of emergency services are the key factors influencing severity of an accident. The application of an automatic incident detection system will allow the emergency services to act instantly through automatic vehicle location system, computer aided dispatch, navigation and guidance, and priorities for emergency vehicles in the street network.

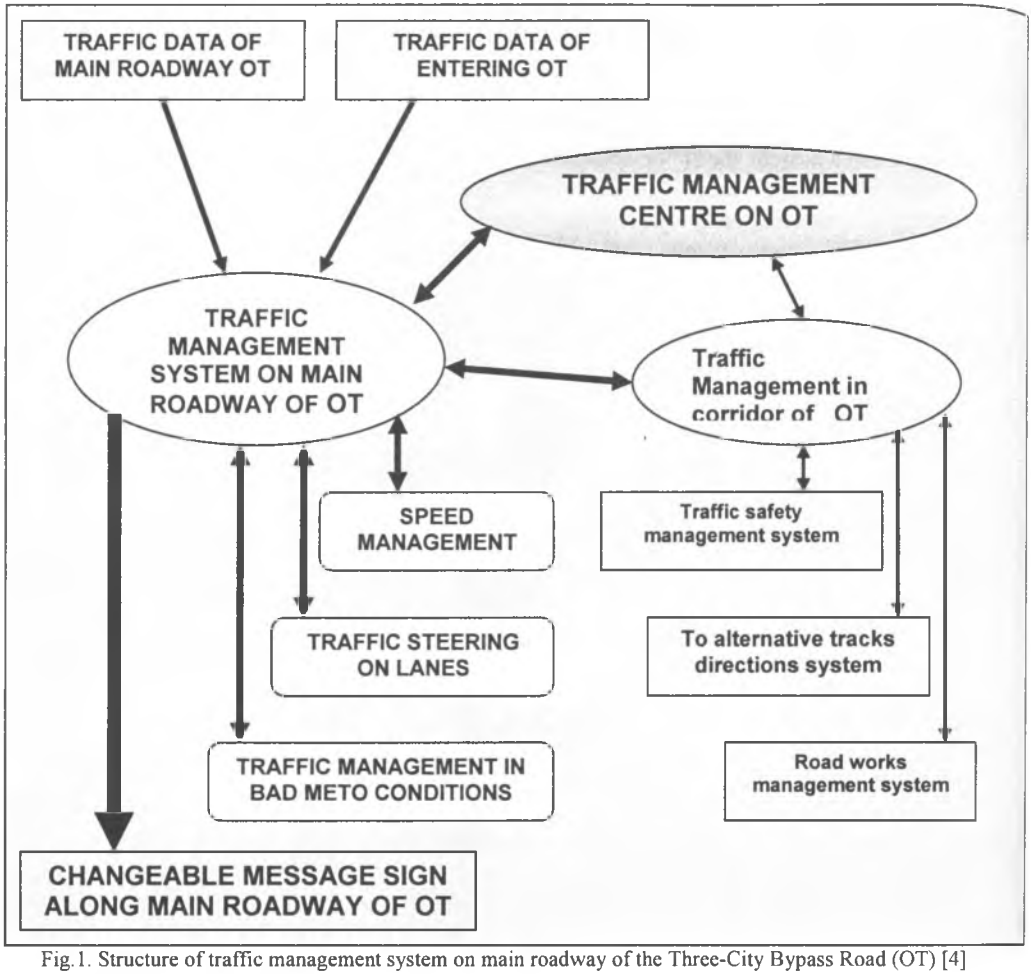

Fig.1. Structure of traffic management system on main roadway of the Three-City Bypass Road (OT) [4]

Road incident management on expressways consists of following functions:

- automatic incident detection,
- communication with the traffic management centre,
- communication with the emergency services departments, and
- rescue fleet vehicles management.

The most important purpose of incident management system is minimization of the impact of non-recurrent events on roads such as car accidents, or vehicle break-down. The system should:

- save life and property of travellers,
- minimize traffic distraction, and
- allow for incident data collection.

Accident management starts when information about an incident reaches the dispatcher in Traffic Management Centre at the OT and finishes when normal traffic conditions are restored. Police, fire department and emergency services are responsible for clearing the scene. They arrive independently; however, their action is coordinated. The OT traffic management kicks in the case of a serious road damage or in the case when a detour is necessary for a longer period of time. The Traffic Control Centre has a very important role which is being responsible for controlling the traffic on the OT corridor so that the traffic distractions are as minimal as possible, and informing travellers with the use of changeable message signs, radio information, SMSs, Internet, and RDS about accident occurrence and preferred traffic detours.

Data collection on the individual OT sections will become one of the key tasks. Data processing block will require additional software to implement incident detection algorithm based on transmitted readings from loop detectors or processed video image. In addition, special equipment for automated vehicle location and software will be needed when the application of rescue vehicles navigation guiding system is to be considered.

The traffic surveillance block will consist of:

- traffic detectors, also used in other systems,
- video cameras located on junctions (to be able to monitor each highway ramp) and between junctions spaced every 1000m.

Data processing block will realize:

- data from detectors analysis and processing – this function could be realized by installations used in other sub-systems. In case of accident identification from video image processing it is necessary to implement an appropriate software for analyses in the Traffic Control Centre,
- collection, transmission, and aggregation of traffic data in the OT traffic management centre and in urban traffic management centers in Gdańsk, Gdynia and also in the regional Crisis Management Centre.

Data transmission will be realized between:

- detectors and data transmission station - cable connections,
- data transmission station and controller in traffic management centre – cable or wireless connection,
- local controller and management centre – wireless connection
- OT Traffic Management Centre and Rescue Management Centre (or Crisis Management Centre) – wireless connection.

Traffic management will be realized with the use of changeable message signs through local controllers also used in other systems.

Travellers' information will be realized with the use of changeable message signs and other means through the Internet, radio signal and RDS.

BIBLIOGRAPHY

[1] BROWNE R., FOO S., HUYNH S., ABDULHAI B., HALL F.. AID CAAT: The Automatic Incident Detection Algorithm Comparison and Analysis Tool. Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

[2] CARRASCO J. A., and LITWIN M. Automatic Incident Detection Using the McMaster Algorithm and Neural Networks. CIV532H Term Project, Department of Civil Engineering, University of Toronto 2002.

[3] EVANCO, M. W. The Impact of Rapid Incident Detections on Freeway Incident Fatalities. Mitretek Report, McLean, VA, 1996.

[4] JAMROZ K., OSKARBSKI J. i inni: Koncepcja systemu sterowania ruchem na drodze krajowej nr 6 na odcinku Obwodnicy Trójmiasta". Politechnika Gdańska, Katedra Inżynierii Drogowej, Gdańsk 2002

[5] KLEIN L.A. *Sensor technologies and data requirement for ITS*. Artech House, Norwood, MA, 2001.

[6] KWON J., and P. VARAIYA M. The Congestion Pie: Delay from Collisions, Potential Ramp Metering Gain, and Excess Demand. Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

[7] MYSZA Z. *Analiza Możliwości Zastosowania Zintegrowanego Systemu Zarządzania Bezpieczeństwem Ruchu na Obwodnicy Trójmiasta*. Master of Science Thesis, Transportation Engineering, Department of Civil and Environmental Engineering, Technical University of Gdańsk, December 2004

[8] OZBAY K., and PUSHKIN K. *Incident Management in Intelligent Transportation Systems*. Artech House Publishers, 1999.

[9] PARKANY E., and XIE Ch. A Complete Review of Incident Detection Algorithms and Their Deployment: What Works and What Doesn't. Report prepared for the New England Transportation Consortium, Project No. 00-7, February 2005.

[10] RODGERS S., WADSWORTH B., SMITH S., FORDE M. An Analysis of Incidents on Europe's Busiest Motorway, the M25, compared to UK motorways and US interstates. Paper presented at the 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

[11] SIMS D. Intelligent Transportation Seminar Awareness Seminar. Benefits and Costs of ITS. Ministry of Transportation, Edmonton, Alberta, IBI Group, 2000.

[12] Transport Canada. An Intelligent Transportation Systems Plan for Canada. En Route to Intelligent Mobility. Report, 1999.

[13] WEILL R., WORTON J., GARCIA-ORTAZ A. Traffic Incident Detection: Sensors and Algorithms. In Mathematical and Computer Modeling, vol. 27, No. 9-11, 1998, pp. 257-291.

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