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Analysis of the Incident Detection Technologies and Algorithms in Intelligent Transport Systems

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Abstract

In this article it was compared the incident detection technologies in intelligent transportation systems. The main factors wereconsidered used for evaluation of existing technologies. It's presented the results of the analysis of the performance criteria of technologies in various environments. The basic advantages and disadvantages of the considered technology for detecting vehicles was described. The evaluation of the effectiveness of incident detection algorithms was found out in the specific area of the road network using of automated data-processing system "CRIS". Ii was considered the factors influencing on the choice of incidents detection algorithm and analyzed the parameters characterizing their performance. For the six analyzed algorithms and the algorithm proposed by the authors it was conducted calculation of quality and shown need for multiple using of algorithms to determine incident on the road.

Keywords: transport system, accident, algorithm, monitoring, situational management, traffic accident, road technology, sensors, criteria of effectiveness.

INTRODUCTION

Congestion becomes daily event on the roads in large cities, as well as has a negative impact on road safety, mobility and performance of the transport system. Therefore, management of road incident is an important component of transport solutions as part of intelligent transport systems (ITS). Development of an effective traffic incident management process can significantly reduce the consequences of road accidents, such as congestion, pollution and the risk of secondary incidents [1].

Aim of any traffic incident management strategy is the elimination of the emerged accident as soon as possoble. Such management should include folowing steps: the detection of incident, response on occurred incident, the restoration of normal traffic conditions [2]. Efficacy is determined by the time characteristic since its inception until its complete elimination.

Effective incident management requires the integrated use of all incoming information about detected incidents from various sources and organization of all involved responders to its resolve [3]. This problem is difficult to solve because of the following reasons:

- Organized and technical fragmentation of existing responders;
- Lack of a common system for the collection and compilation of information about any incidents on the roads, alert and interaction of all concerned traffic control services.

In real life it is very hard and difficult to develop a unified set of scenarios by which activities will be undertaken to eliminate the emerged incident. Nowadays, the development and implementation of incident management scenarios are based mostly on personal experience of the personnel who work in incident management centers. Therefore, for the accurate detection and analysis of incidents it is necessary to develop appropriate algorithms and techniques that allow performing automatical a primary diagnosis of emerged incident and offer the best solutions to eliminate the incident.

COMPARISON OF THE INCIDENT DETECTION TECHNOLOGIES IN ITS

Traffic incident is generally defined as an event that has negative consequences, namely creates dangerous driving conditions and / or limits the traffic flow [4]. There are different events that can lead to a temporary reduction of traffic capacity. These events can be divided according to the probability of occurrence:

- Predictable and / or planned, such as construction or repair work, maintenance, entertainment or sports events, marches and parades, the situation on the roads due to adverse weather conditions, the occurrence of congestion during peak periods, etc.;

- Unpredictable and / or unplanned, such as traffic accidents, broken or stopped car on the road, lost cargo, and other accidents that may occur suddenly and as a result reduce traffic flow.

Also these events can be classified according to the type of cause of the trouble:

- Traffic accident: both with minor vehicle damage, and with victims or with a fatal outcome;
- Garbage and other barriers on the way (fallen lamppost, a tree, a defect on the road, etc.);
- Activities of for maintenance of roads or carrying out different types of events (entertainment, sports, etc.);
- Unexpected congestion;
- Any combination of the above mentioned events.

Another cause of congestion can be extreme weather conditions such as heavy rain or storms. Congestion creates serious problems in urban areas. Accumulations of vehicles, as stated earlier, are of two types: recurring and non-recurring congestions. Predictable events, such as sporting and cultural events or recurring events (eg, congestion, occurring in peak periods) in this work are not considered because of the possibility of a planned action to minimize their impact on traffic. This article considers incidents as non-recurring, unpredictable or unpredictable congestion. The main factors to be used for evaluation of existing technologies for the detection of vehicles [5]:

- Reliability, is the most important and main factor. For example, frequent crashes and breakages detectors can seriously hamper the performance of all necessary operations in the traffic management system.
- Performance under various environmental conditions (rain, fog, snow, etc.). This factor is also one of important.
- The accuracy of obtained data from detectors. The accuracy of the data is an important factor, which is largely dependent on the installation and calibration of the sensor. Other words, if the sensor is not properly installed and calibrated, it will be impossible to guarantee the accuracy of the data.
- Performance in real time. Performance in real time of any sensor plays a critical role in ensuring timely decisions. In the past, this factor was not important because the resulting data were used in the offline systemx. At present the problem is solved by the use of widely available high-speed communications technology.

In addition to the above factors, the cost of implementing the technology plays a crucial role in the choice of sensors for monitoring subsystem. Other words, technology that provides excellent results in terms of the four main factors, it will be highly undesirable if its implementation will be expensive compared to other available technologies.

Analysis of the performance criteria under various environments for different detector technologies is presented in Table 1 [6].

Table 1. Environmental conditions for different technologies.

Technology	Environmental conditions										
	Clear day	Clear night	Hot day	Light breeze	Strong wind	Light rain	Heavy rain	Light snow	Heavy snow	Fog	Smoke
Inductive loop detector	✓	✓	✓	✓	✓	✓	✓			✓	✓
Magnetometer	✓	✓	✓	✓	✓	✓	✓			✓	✓
Infared (pas + act)	✓	✓	✓	✓	✓					✓	
Acoustic	✓	✓						✓	✓	✓	
Ultrasonic	✓	✓		✓		✓		✓			
Micriwave (Radar)	✓	✓									

The results in the table clearly shows that various sensors that use different technologies may work better, depending on the specific environmental conditions, such as fog, rain, snow, etc. A simple example is the using of technology induction loops, which shows poor performance when the snow covers the road surface. Analysis of the factors needed to select the optimum sensor for a region with certain weather conditions. For example, such sensors are impractical to install in regions where precipitation falls as snow, in contrast to the acoustic sensors, which are in the same conditions show the best result.

In terms of weather conditions inherent to the Moscow region, the acoustic and ultrasonic sensors are suitable for snowy weather. However, these techniques show poor performance in windy weather. Therefore, for the other weather conditions (such as rain, wind, etc.) need to be considered such sensors like the inductive loop sensors and magnetometers.

The important in choosing of technology is analysis of data that can be obtained by monitoring the traffic in real-time.It should be noted that the choice of a technology directly depends on the incident detection because different algorithms are needed for different types of data [7]. Table 2 shows various types of information that can be obtained by using various technologies.

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Table 2. Types of data from sensors.

Technology	Volume	Speed	Classification	Location	Density	Distance between vehicles
Inductive loop detector	✓	✓	✓	✓		✓
Magnetometer	✓	✓	✓	✓		
Infared (act)	✓	✓				
Infared (pas)	✓	✓		✓	✓	
Acoustic	✓			✓		
Ultrasonic	✓	✓	✓	✓	✓	✓
Micriwave (Radar)	✓	✓	✓	✓	✓	

The best result was shown by ultrasound technology, through which it is possible to get the maximum amount of different data. The choice of sensor technology influences on the type of used incident detection algorithm, because various sensors can measure a variety of traffic data, and various algorithms use different types of data. Thus, in processing of the choice of technology for vehicles detection and incident detection method, it should be analyzed for their compatibility.

In this study, incident detection algorithm uses the traffic characteristics of both the vehicle speed and the flux density. To implement the proposed algorithm all sensors fit except the detectors based on acoustic technology, because using this technology it is not possible to measure the speed of the vehicle. Next will be considered the main advantages and disadvantages of discussed technologies of vehicles detection (Table 3):

Table 3. Advantages and disadvantages of each technology.

Type	Advantages	Disadvantages
Inductive loop detector	• Relatively low cost • Large knowledge base • Relatively good performance	• Installation and maintenance require stopping of traffic • Can be damaged by heavy vehicles, road repair, etc.
Micriwave (Radar)	• Installation and repair do not require stopping of traffic • Compact size	• Relatively low accuracy of data
Active infared	• No data	• Can be damaged by strong precipitation in bad weather and poor visibility • High price
Passive infared	• Installation and repair do not require stopping of traffic • Better than visible wavelength sensors in fog • Compact size	• Have an unstable detection zone • One sensor is focused on collecting information from one lane
Ultrasonic	A wide range of received traffic data	• The signal can be attenuated or distorted because of environmental factors (changes in ambient temperature, air turbulence and humidity) • Poorly detect covered by snow cars
Magnetometer	Suitable for installation in a bridge or other solid surfaces, where the other detectors can not be installed	• Limited in the use of • Average cost
Video image processing	• Provides an image of movement in real-time • Monitor simultaneously with several lanes • No traffic interruption for installation and repair	• It is required expensive data transmission equipment • Different algorithms are usually required for day and night use • Possible errors in data of traffic • Exposed to atmospheric changes and adverse weather conditions

Installation of microwave sensors and infrared sensors does not require overlap of traffic and these sensors have compact sizes, but show poor performance, as must be used in a good (clear) weather. Infrared sensors show poor performance in bad weather (in the rain and snow).

Using ultrasonic sensors a variety of traffic data can be received, but performance of sensor depends directly on the weather, namely in bad weather it is possible distortion of information received from the sensors. For all the above parameters of induction loops, despite its shortcomings (for example, show poor performance in snowy weather)as compared with other sensors have many advantages [8]:

- Low cost, which directly affects the consumption and operating.
- Using this sensor it is possible to obtain a variety of information about traffic flow.
- Performs well under various weather conditions, the exclusion of snowy weather.
- Inductive loop detector are the most popular type of sensor, the presently a large knowledge base are collected.

In order to ensure a timely and appropriate emergency response on emerged incidents, in the incident detection system accurate information should come from different type of source such as the location, type, scale and severity of the incident. Combining of sensors can bring the benefits of each sensor in onesystem.

EVALUATING THE EFFECTIVENESS OF INCIDENT DETECTION ALGORITHMS

For realization of incident detection algorithm, photo radar complex "CRIS" C was used included two photo radar sensors. During the implementation of the incidents detection algorithm inductive sensors were not considered, because for their installation it was necessary to stop the traffic that could lead to sharp increase the congestion on the test section of the road [9]:

- The composition of the photo radar "CRIS" sensor;
- Radar with flat antenna (rate measuring «ISKRA» DA/210);
- Specialized industrial computer;
- Highly sensitive television camera;
- Infrared illuminators;
- Power transmission / reception of data;
- Power Supply;

Sensors have been installed along the Mytishchi street in the distance 500 meters from each other to measure the traffic coming from the Fabrychnaya street and 100 meters before the traffic light at the intersection with the street Sovkhoznaya 5 meters above the road (Figure 1).

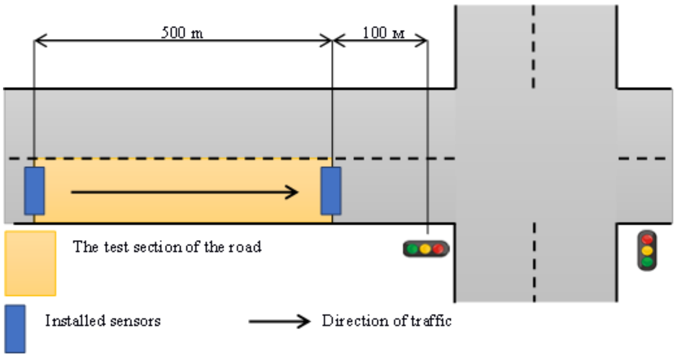

Figure 1: Siting the implementation of incident detection algorithm.

Sensors have been installed for a certain distance from the intersection to avoid getting in the statistic cars that can reduce the rate or completely stop before the intersection, and thus the algorithm may show more numbers of false signals.

Traffic information on the test section of the road is collected and analyzed for a month in offline mode. For data collection the automated data processing system "CRIS" was used (installed on the storage server), which also provides the functionality and performance of all installed equipment. Sub-program "Statistics", included in the data center "CRIS", provides collection and processing of static data and allowed to receive data about the number of cars that passed through the test section of the road and the intensity of traffic.

During the implementation and analysis of data about traffic incidents following results have been obtained: number of determined incidents on the road amounted 90% (this index is worse than in the simulation of algorithm). This result is explained by the fact that the system could not detect an incident in low road congestion, for example, at night. Also, other drawbacks were identified that need to be considered in further research and development of incident detection algorithms on the road:

- The number of false alarms sharply increased in peak hours, for example, in the morning.
- Also during the analysis of the data other legitimate intervals have been identified in which no occurrence of incident the system shown its presence.
- This information can be used to reprogram the algorithm installed on a traffic light on the intersection.
- This method can be used in services notification of congestion on the road, by displaying a traffic indication on interactive maps in the Internet and on the scoreboard, placed on the roadway.

The following expression is used within the framework of this research for the analysis of effectiveness:

$$F(x_1 \dots x_n, y_1 \dots y_n) = x_1y_1 + x_2y_2 + \dots + x_ny_n \quad (1)$$

where x - the weight of each criterion that will determined by the results conducted research;

y – the importance of each criterion;

$n \in N$ – indicates the number of criteria.

The basis is the method of analytic hierarchy from decision theory, which consists of four required steps:

1. step: Drafting of structure "The Aim – The criteria – The alternatives";
2. step: Pairwise comparison of criteria;
3. step: Calculations of criteria weights;
4. step: The calculation of the quality indicator for each of the alternatives.

Next, it's necessary to consider in detail the applicability of each stage to the research (Table 4):

Table 4. The structure of "The Aim – The criteria – The alternatives" for this study.

<table>
<tr><td colspan="2">The aim – The choice of an optimal algorithm for the incident detection</td></tr>
<tr><td>The criteria:
• Number of detected incidents
• The number of false alarms
• Incident detection time</td><td>The alternatives:
• California Algorithm TSC#7
• APID Algorithm
• PATREG Algorithm
• SND Algorithm
• Bayesian Algorithm
• McMacter Algorithm
• The developed algorithm based on fuzzy logic</td></tr>
</table>

Stages 2 and 3 were adapted, because in the original form they are not suitable. After each study, each criterion is respectively assigned a weight that will be defined as follows: algorithm with the best result will be assigned maximum weight of criterion (the scale of criteria weights and their values are presented below). The weight of the rest will be calculated relative to the maximum result. It has proposed the following scale of criteria weights and their values (Table 5):

Table 5. Scale of criteria weights and their values.

The value of weight	5	4	3	2	1
The value of result	best	good	average	satisfactory	worst

The following formula is used for calculating the quality indicator**:**

$$S_j = \sum_{i=1}^{N} w_i V_{ji} \quad (2)$$

where S_j - quality index of j-th alternative i.e. of the algorithm;

N - the total number of criterion ($N = 3$);

w_i - i-th weight criterion, which is calculated in the experiments;

V_{ji} - the importance of the i-th criterion. Since each of the considered criteria are equally important for the evaluation of the algorithms, so the importance of the i-th criterion are all equal to 1 ($V_{ji} = 1$).

DETERMINATION OF MEASURES OF ALGORITHMS EFFECTIVENESS

The effectiveness of traffic incident management system is related primarily with the implementation of phase of the incident detection. The following parameters are considered that characterize the effectiveness of incident detection algorithms [10]:

• MTTD (Mean Time to Detection), defined as the time from the moment how incident occurred until its detection:

$$MTTD = \sum_{i=1}^{N} (t_a - t_{inc})/n \quad (3)$$

where N – the number of detected incidents,

t_a – time when the incident was detected,

t_{inc} – time when the incident occurred.

Detection of the incident can be seen as a critical component of the total incident management process [11]. As soon as the incident is detected and checked, the event will be launched to eliminate the emerged incident. In order to ensure effectiveness of any incident management process it is important that emerged the incident was detected, as soon as it appeared. Timely and accurate incident management becomes more important when the negative impact on road traffic and its safety is considered. The delay in the identification of the incident could lead to a long congestion on the road, which, in turn, may become the main cause of secondary accidents [12].

There is a direct relationship between the time required for the detection of the incident and the severity of the consequences. For example, a major fire in the Mont Blanc tunnel linking France and Италии and through which daily dozens of trucks and cars pass. The fire occurred on 24 March in 1999 (Fire alarm went off immediately, the sensors fixed fire), it was extinguished after 56 hours. As a result 39 people died. The tunnel was repaired and implemented back into service in 2002. But after this incident, the European safety standards that govern the equipment used and the equipment of tunnels in the European Union have undergone significant changes. Among other standards started to prescribe the the mandatory installation of incident detection systems (IDS) in the tunnels over a certain length. So in this tunnel the latest surveillance system and firefighting were installed [13].

Another important advantage of the rapid detection of traffic incident is a possible reduction the probability of occurrence accidents. Mortality is considered as the death of a participant in a car accident within 30 days from the date of this event [14]. The Evanko's research in 1990 shows the dependence of the injuries severity from time. The first results showed that the use of more efficient methods of detection of incidents could reduce the impact of road incident on average 2-3 minutes, at an average of 5.2 minutes. In the same survey Poisson regression was reviewed which estimated the number of victims, depending on such variables:

- VMT – vehicle miles traveled,
- MVS – mean vehicle speed,
- ACC – alcohol consumptionper capita,
- YAD - young/aged driver,
- ANT – accident notification time,
- IPC – personal income per capita.

The dependence on aforementioned variables is as follows:

$$\ln(\mathrm{NF_i}) = a_0 + a_1(\mathrm{VMT_i}) + a_2(\mathrm{MVS_i}) + a_3(\mathrm{ACC_i}) + a_4(\mathrm{YAD_i}) + a_5(\mathrm{ANT_i}) + a_6(\mathrm{IPC_i}) \quad (4)$$

where i - index indicating state in the United States;

ln() - natural logarithm;

$a_0, a_1, a_2, a_3, a_4, a_5, a_6$– parameters of the model that must be estimated using the actual data of incidents.

Important to note that research of Evanko focuses on urban freeways. In total, there 2331 fatalities were considered on 11,500 miles of urban freeways, thus, the results reflect the total number of fatalities on urban freeways, instead the total number of fatalities on the roads (including on highways and motorways) in the United States [15]. The following equation is used to determine the impact of change of the notification time (ANT) to change number of fatalities (NF):

$$\frac{\Delta \mathrm{NF}}{\mathrm{NF}} = 0{,}27\frac{\Delta \mathrm{ANT}}{\mathrm{ANT}} \quad (5)$$

From this equation, it follows that if the 5.2-minute notification of an accident reduce to 3 minutes using more efficient methods of incident detection, it is possible to reduce the number of fatalities on 11% in total that is 246 deaths per year.

It should be noted that in this study was considered extremely reducing the time of incident detection, but not its duration in whole. Nevertheless, the results of this research project show the importance of the rapid detection of the incident in terms of the saving lives and reducing costs associated with traffic accident.

- DR (DetectionRate), defined as ratio number of detected incidents to the total number of incidents, (measured in %). This parameter depends on the definition of the incident, namely depending on what the system will be considered as an incident, and what is not. These parameters are calculated as follows:

$$\mathrm{DR} = \left(\frac{\mathrm{N_{DI}}}{\mathrm{N_{TI}}}\right) * 100 \quad (6)$$

where $\mathrm{N_{DI}}$ - the number of detected incidents,

$\mathrm{N_{TI}}$ - the total number of incidents.

- FAR (FalseAlarmRate), – defined as the percentage of error signals of detection to the total number of incidents:

$$\mathrm{FAR} = \left(\frac{\mathrm{N_{FA}}}{\mathrm{N_{TA}}}\right) * 100 \quad (7)$$

where $\mathrm{N_{FA}}$ – the number of false alarms,

$\mathrm{N_{TA}}$ – the total number of alarms.

In works (Min, 2004) various factors were generalized, affecting the efficiency of the automatic incident detection algorithms. These factors include, but are not limited to:

1) Road operating conditions (heavy / medium / light / at full capacity);

2) The geometric factors (road category, the presence of the shoulder, ramps, etc.);

3) Environmental factors (dry, wet snow, sleet, fog, etc.);

4) The duration of the incident;

5) The degree of incident severity;

6) The distance between the detectors / sensors;

7) The location of the incident (in relation to the detector).

These factors are so complex so it is very difficult to consider all them in one algorithm. None of the existing algorithms was developed for the consideration of all these factors.

There is a comparative analysis of the main indicators of the effectiveness of the measures according to the study of algorithms [16] and the previous results of research developed algorithm based on fuzzy logic below [17]. The number of detected incidents (DR) (Figure 2).

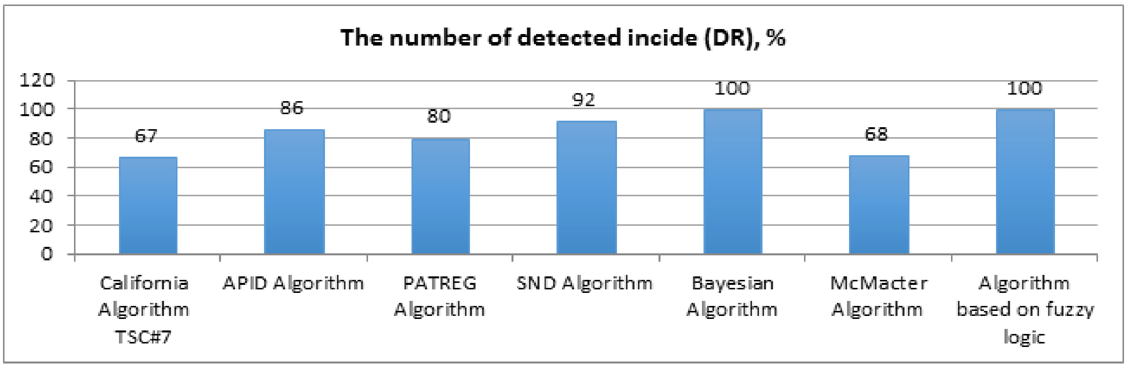

Figure 2: The results of incident detection level research.

The maximum values observed for the two algorithms: Bayes algorithm and developed algorithms based on fuzzy logic - 100%. In addition, SND algorithm has a high indicator – above 90%. Caloformia and McMaster have the least values, below 70%. The number of false alarms (FAR) (Figure 3).

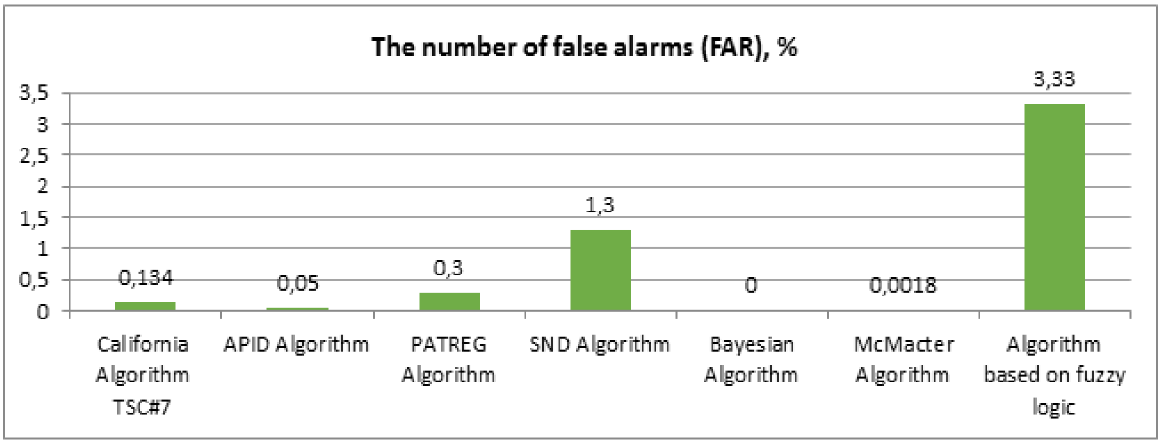

Figure 3: The result of the research the number of false alarms.

The Bayesian algorithm has the least values of alse alarms number – 0%, that mean exception errors in the system. APID and McMaster algorithms - 0.05% and 0.0018%, respectively, own other minimum indicators. The developed algorithm based on fuzzy logic has the most value – 3.33%. There were 4 false alarms in 90 conducted experiments. Incident detection time (MTTD) (Figure 4).

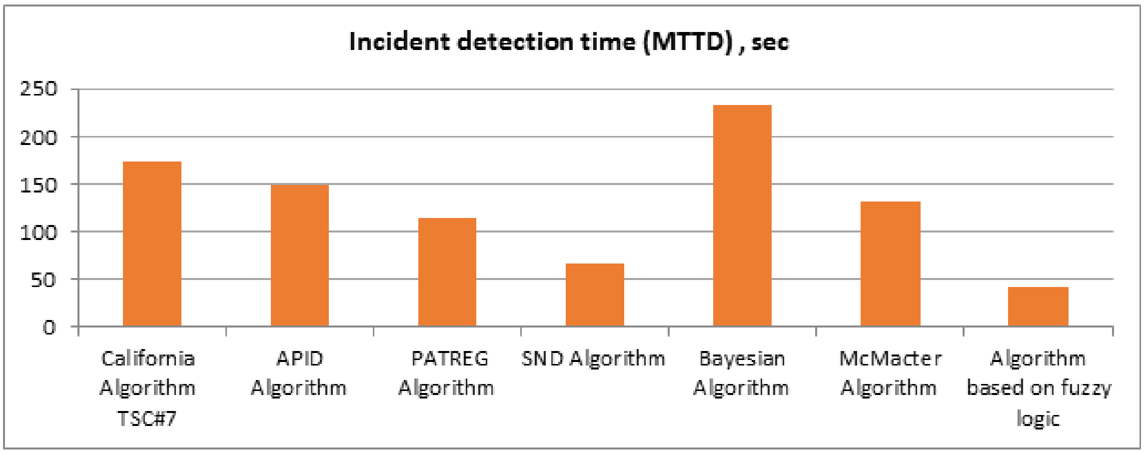

Figure 4: Results of the study time incident detection.

The maximum detection time of incidents was got by in Bayesian algorithm - almost 4 minutes, California has almost 3 minutes. The least value inheres developed algorithm based on fuzzy logic (less 1 minute – 41.02 sec).

The evaluation of discussed above algorithms of incident detection will be carry out according to the proposed method of performance evaluation [18]. According to 3-th stage, it is necessary to calculate the wieght for each criterion. The following values were calculated (Table 6).

Table 6. The weights for each criterion, depending on the algorithm.

Algorithm	The criteria		
	The number of detected incidents (DR)	The number of false alarms (FAR)	Incident detection time (MTTD)
California Algorithm TSC#7	6,7	9,6	3,07
APID Algorithm	8,6	9,85	4,35
PATREG Algorithm	8	9,1	6,22
SND Algorithm	9,2	6,09	8,7
Bayesian Algorithm	10	10	1
McMacter Algorithm	6,8	10	5,29
Algorithm based on fuzzy logic	10	1	10

It should be calculated indicator of quality S_j for each algorithm according to the formula (2):

$$S_{TS\#7} = 6{,}7 + 9{,}6 + 3{,}07 = 19{,}37$$

$$S_{APID} = 8{,}6 + 9{,}85 + 4{,}35 = 22{,}8$$

$$S_{PATREG} = 8 + 9{,}1 + 6{,}22 = 23{,}32$$

$$S_{SND} = 9{,}2 + 6{,}09 + 8{,}7 = 23{,}99$$

$$S_{BAYES} = 10 + 10 + 1 = 21$$

$$S_{McMaster} = 6{,}8 + 10 + 5{,}29 = 22{,}09$$

$$S_{FL} = 10 + 1 + 10 = 21$$

SND algorithm has the best result, Calofornia has the worst. Developed algorithm based on fuzzy logic has average indicator. It should be noted that the values obtained quality indicators are the small difference, due to the fact that each of the considered algorithms in a given criteria performed better or worse results, but none of that would have shown the best results in all.

For example, the proposed algorithm based on fuzzy logic has the minimum detection time and the number of false alarms, but it has the highest level of false alarm. On the other hand, despite the fact that Bayesian algorithm allow to detect all incidents and has a zero rate of false alarms, but the its time of the incident detection is the largest. SND algorithm, which is a leader in the comparative analysis, shows one of the best results in terms of the number of detected incidents and detection time, but it has one of the worst rates in the number of false alarms.

CONCLUSION

Typical programs for traffic management, as a rule, consist of conventional and automatic incident detection systems. Conventional detection systems consist of patrol services or systems for the processing of incoming telephone calls by means of which report the road incident [19].

In order to ensure adequate response to traffic incident it is necessary to obtain accurate information about the location, type and scale of the incident. Using sensors to detect traffic incidents allows obtaining more complete, accurate and timely information about the traffic situation.

Most of the automatic detection system cannot detect the incident until the shock wave does not reach the flow of traffic to the nearest sensor, when the system will begin to measure the character of the traffic. To improve the efficiency of incident detection system it is necessary to collect data from several sources, such as inductive sensors and video cameras. Using several sensors at the same time can reduce the impact of disadvantages of each of the sensors to reduce the incident detection time, which generally increase the overall performance of the incident detection system. For example, the signal of the occurrence of a road incident, information about which came from the inductive loop detector can be confirmed visually by pointing the camera on the intended area with road emerged incident.

Access to the data of traffic incident by sensors will not bring any benefit in the process of incident management. Although there is a huge amount of research and literature aboyt incident detection algorithms, they all have a common characteristic. Already in May 1975, it was found that "the detection of incidents is totally dependent on disturbances or sudden change of traffic conditions". The scale of these disturbances, of course, depend on the conditions existing, for example in traffic (speed, severity and location of the incident).

Considering the characteristics of the traffic and the data from the system, the solution of incident management problem cannot be done using numerical algorithms. Therefore, the presence of an expert is required, using his knowledge and experience [20]. When an incident is detected, the operator must perform various procedures for its elimination. Using this method is difficult to improve the traffic incident management process, because the process of responding to the incident cannot be accurately and clearly described. To solve this problem, it is needed to formulate a real response algorithm procedure for the operator on the incident and to develop an automated decision-making system, which should take the place of the operator.

Uncertainty management is one of the most significant characteristics of the decision-making process of fuzzy logic [21]. Therefore, the application of fuzzy systems was suitable as a solution to problems in the management of traffic incidents. The algorithm based on fuzzy logic has shown good results in the total number determined incidents (100%) and the lowest detection time of an incident (41, 02 seconds).

It should be noted that the feature of each algorithm defines its own application environment. Because the performance one and the same algorithm may vary for different environments: ecological factors, the geometric features of the roadway, the types used to collect sensor data, their configuration and calibration, the period of data collection, as well as factors that directly affect the traffic. In this case, is necessary to use the ght algorithm to combine several algorithms for determining the incident or the probability of its occurrence. The efficiency of incidents detection is increased by combining the benefits and features of each of the algorithms. So, most algorithms work best at low and medium volumes of traffic, while some of them are specifically adapted for high volume of traffic. By combining these algorithms, the incident will be detected with a higher probability than when theu are used separately. Ultimately, it allows to improve the overall performance of traffic incident detection system.

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