LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2016, VOL. 11, NO. 16, 9060-9078

Simulation of Automatic Incidents Detection Algorithm on the Transport Network

Andrey B. Nikolaev[a], Yuliya S. Sapego[a], Anatolij N. Jakubovich[a], Leonid I. Berner[b] and Andrey M. Ivakhnenko[a]

[a]Federal State Funded Educational Institution of Highest Education "Moscow Automobile and Road Construction State Technical University – MADI", Moscow, RUSSIA; [b]JSC "AtlanticTransgasSystem", Moscow, RUSSIA

ABSTRACT

Management of traffic incident is a functional part of the whole approach to solving traffic problems in the framework of intelligent transport systems. Development of an effective process of traffic incident management is an important part of the transport system. In this research, it's suggested algorithm based on fuzzy logic to detect traffic incidents and determine its priority for transmission information about incident to emergency services. Sensors that are installed on the roadway provide the data for algorithm of incident detection. After the incident is detected, the algorithm of defining its priorities will be started. The traffic flow for research will be modeled in the PTV Vissim, after all receives information will be uploaded to excel for further processing.

KEYWORDS
System of incident management, Intelligent Transport System, PTV Vissim, fuzzy logic

ARTICLE HISTORY
Received 20 March 2016
Revised 28 April 2016
Accepted 19 May 2016

Introduction

The congestion is major problem on the road in the urban cities, so one of the important part of ITS (Intelligent Transport System) is incident detection system. It is important to create an effective system of determining the incident (Hourdos & Garg, 2008).

The system of traffic incident management has to deal with many uncontrolled and uncontrollable factors that are difficult to predict and take into account in the planning of decisions, such as weather conditions, the condition of roads, the physical and moral driver of operators (Alkandari, 2013; Akhmadieva, 2015; Akhmadieva & Minnikhanov, 2015; Sultangazinov et al., 2016; Bulat & Volkov, 2016). For the process of traffic incident, the system it is necessary to develop a decision support system based on the mathematical apparatus of

CORRESPONDENCE Andrey B. Nikolaev ✉ nikolaev.madi@mail.ru

assessing situations and selection based on them the required control action (Deniz & Celikoglub, 2011). Such a system may be implemented based on fuzzy situational management (Simankov & Shopin, 2004; Toymentseva et al., 2016).

In this research it's suggested algorithm based on fuzzy logic to detect traffic incidents and determine its priority for transmission information about incident to emergency services (Nikolaev & Sapego, 2015). The data for the algorithm may come from the sensors installed on the roadway, as well as from drivers, emergency services, etc (Mitrovich, Valenti & Mancini, 2006):

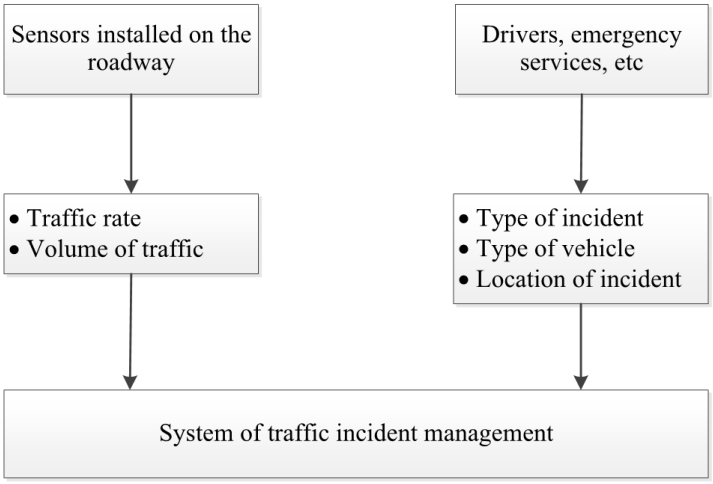

Figure 1. The scheme of obtaining the input data

Information on the current flow rate and volume of traffic can be obtained from the sensors without human intervention (Mahmassani et al., 1999). However, such information as the type of incident, the vehicle type and location cannot be obtained without human intervention. For example, when the notification of the presence of the incident, the controller installed on the road by camera can determine at what point an incident occurred and what types of vehicles (TC) are involved in it (Manstetten & Maichle, 1996).

In this paper it presents results of proposed algorithm simulations in real-time using a modeling system PTV Vissim ("What keeps traffic flowing", n.d.). There are sensors (analogue of induction loops) on the tested section of the road are located. Data from the sensors is collected for each predetermined period and unloaded in an excel file. The received data are analyzed for the presence of the incident (Škorput, Mandžuka & Jelušić, 2010). If the incident is detected, the algorithm of defining its priorities will be started. In addition to determining the priority algorithm, the system sends a notification to the appropriate emergency services with information about occurred incident.

Materials and Methods

Simulation of incidents in PTV Vissim

Software PTV VISSIM is microscopic simulators stochastic traffic. It was used to create a detailed model of I-210 West. In the past, it used mainly as a tool for the design of urban public transport systems, but later it is used to

simulate traffic on the highway. The Model of traffic is based on the work (R. Wiedemann, 1991) combined the perceptual patterns of behavior of drivers with car models (Gomes, 2004).

The behavioral model for drivers includes classifying of reactions in response to the speed and distance relative to the preceding vehicle (Gettman et al., 2008). Drivers may decide to change lanes. This decision may be ("PTV optima and safety smart traffic control for smart cities", 2014):

— Forced - according to the routing requirements, for example, when approaching an intersection;

— Independent - to gain access to a free lane.

PTV Vissim suggests some of the stochastic variation of parameters such as the desired speed and acceleration.

Configuring the simulation parameters

The data for the simulation of the incident will be generated in the software PTV Vissim. Vissim has not real model of incident simulations, so the data will be collected through the creation of parking space on the roadway, which will be considered as a road accident (Tian & Dong, 2012). Three different locations of incident will be modeled in research relatively sensors.

The following road setting is installed in PTV Vissim (see Figure 2):

— The number of lanes in the same direction - 2 lanes;

— The width of the roadway – 3.5 m (width is based the average value of the width of the for normal use roads of different categories according to GOST R 52398) ("GOST R 52398. The classification of highways. The main parameters and requirements");

— The length of the roadway – 1000 m.

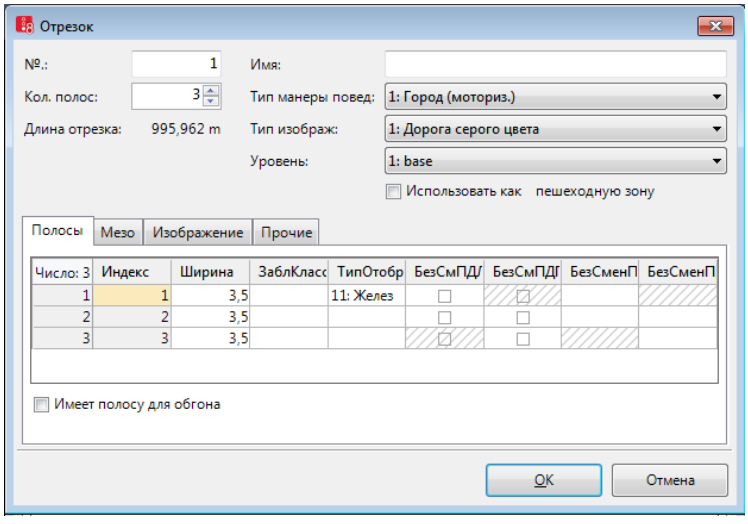

Figure 2. Installed road setting

Configuring of parking space (see Figure 3):

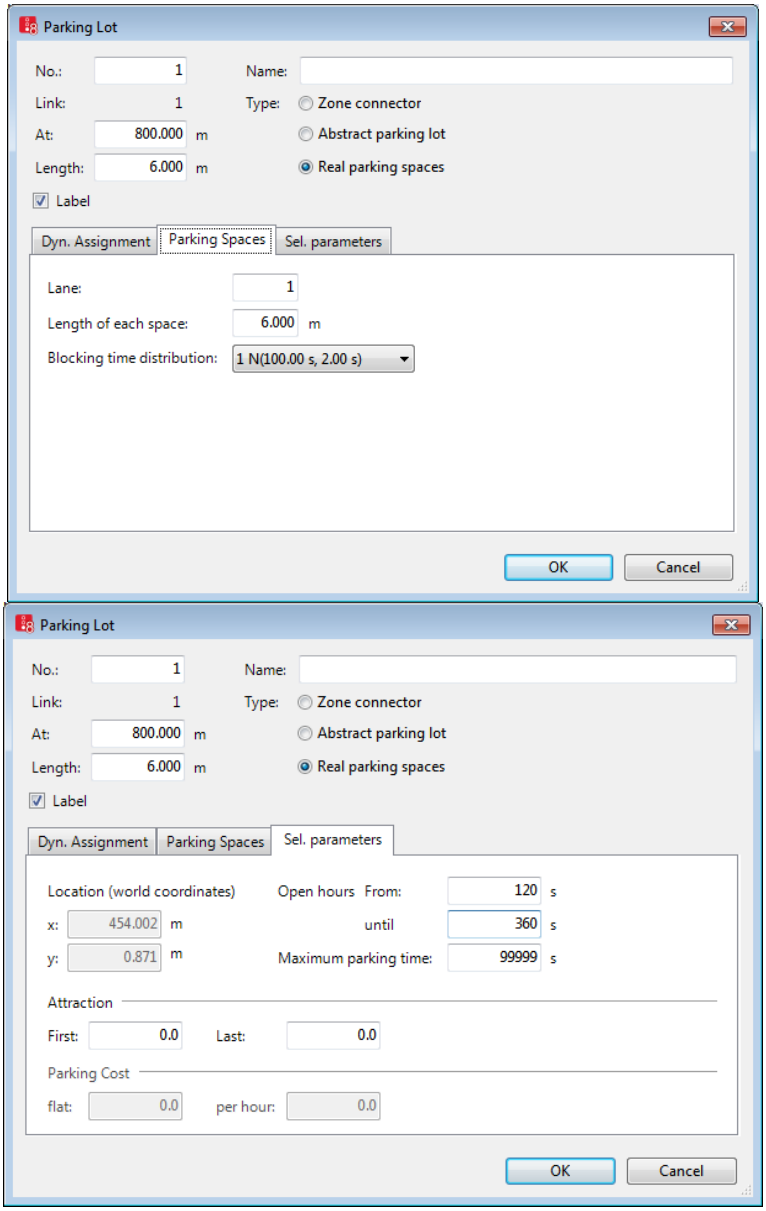

Figure 3. Configuring of parking space

On the road it is created one parking space which is symbolized the stopping of the vehicle, for example, due to damage). It is configured the residence time of the car at the parking place (an average of 100 seconds) in order to during the time for downtime congestion of vehicles may be formed for further analysis. In addition, for the parking space it set of work time in order the cars do not stop during the whole simulation time, but at a certain time to analyze the state of the traffic when the incident did not happen.

Configuring of traffic flow composition with the desired speed is shown in Figure 4:

Count: 3	VehType	DesSpeedDistr	RelFlow
1	100: Автомобиль	60: 60 км/ч	0,950
2	200: HGV	60: 60 км/ч	0,020
3	300: Автобус	60: 60 км/ч	0,030

Figure 4. The composition of the of traffic flow

Because in the city speed limit must be 60 km/h, so for all type of vehicles the desired speed is set to 50 km/h ("DesSpeedDistr" parameter). The percentage ratio sets for all type of vehicles: passenger cars – 95%, HGVs (Heavy goods vehicle) – 0,02%, buses – 0,03% ("Transport streams. The intensity and composition on the federal highway, Moscow region", n.d.).

Setting the traffic flow is presented in Figure 5:

Count: 1	No	Name	Link	Volume(0)	VehComp(0)
1	1		1	2000,0	1: По умолчанию

Figure 5. Setting of the traffic flow with volume value - 2000 auth / h

It's necessary to analyze the efficiency of the algorithm in a variety of driving conditions; therefore, test will be included 3 different value of traffic volume: 2000 auth/h, 4000 auth/h, 8000 auth/h.

Setting of detector (an analogue of inductive loops) is shown in Figure 6. The distance between the measurement points is set 500 meters.

Count: 4	No	Name	Lane	Pos
1	1	Датчик 11	1 - 1	900,000
2	2	Датчик 12	1 - 2	900,000
3	3	Датчик 21	1 - 1	400,000
4	4	Датчик 22	1 - 2	400,000

Figure 6. Information about on installed detectors on the roadway

Incidents (parking spaces) will be established at three different locations (see Figure 7):

1. At a distance of 100 meters after the installation of the first detector.
2. Exactly halfway between the detectors (at a distance of 250 meters).
3. At a distance of 100 meters before the installation of the first detector.

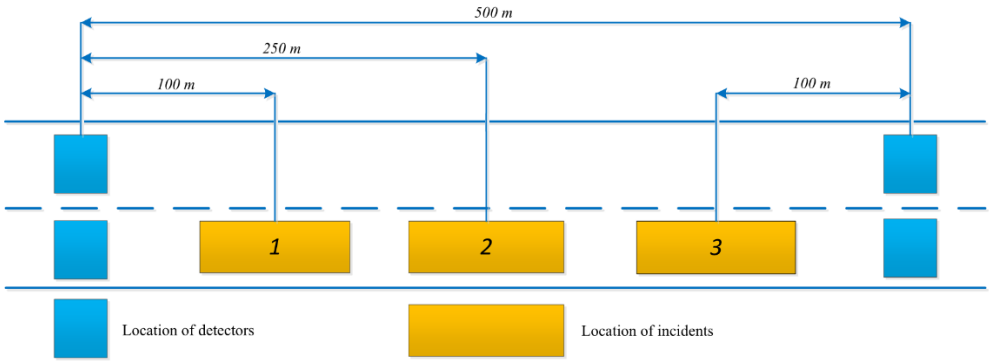

Figure 7. Positions of detectors and incidents (parking places)

Data from the detectors come every 30 seconds to the system. Proposed algorithm of incident detection will be tested in 3 different values of traffic volume and in 3 different locations. The result is 9 different scenarios.

Results

Description of experiments

9 various experiments were performed with different traffic conditions in PTV Vissim:

a) The parking the place was located in three different locations (after 100 m, in the middle, before 100 m).

b) Trafficflowwas changed (2000 autm/h, 4000 autm/hand 8000 autm/h).

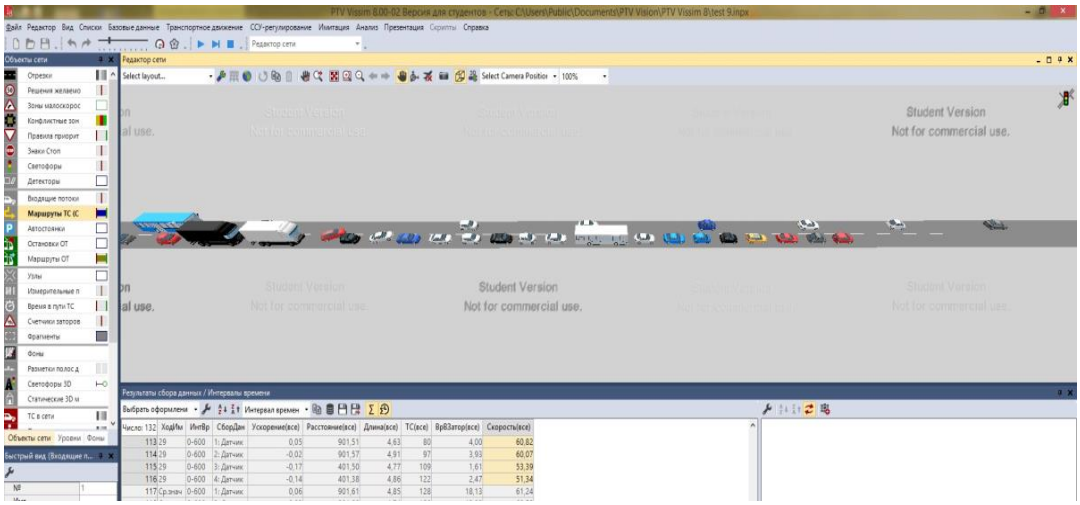

Figure 8. Screen of simulation of traffic when an incident occurred

The simulation results were unloaded in an excel file. The following data will be analyzed on the effectiveness of the proposed algorithm based on fuzzy logic (Parkany, 2005):

— Incident detection time: from time when incident occurred (when the car stopped at the parking place) until time when system will show the first deviation from the normal traffic.

— Total number of detected incidents: total number of incidents detected by the system (when the system showed that the incident actually occurred).

— The number of false alarms: number of signals when the system showed that the incident occurred, but in fact, it is not on the road.

As a result of the algorithm the following data will be obtained for each experiment:

1. Time ("Время"): current time of simulation.
2. Incident ("Инц"): it shows the time interval of the incident action (when the car stops at the parking place)
3. Status ("Статус "):incident status that the system displays at the current time:

I. Green – normal traffic;
II. Yellow - probability of occurrence of the incident;
III. Red - incident is detected.

Also the number of fuzzy rules is displays.

— Amount ("Количество"): the average number of vehicles that passed through the detector in 30 seconds (the first two lines represent data received from the second sensor, the last two – from the first detector).

— Rate ("Скорость"): average flow rate (the first two lines represent data received from the second sensor, the last two – from the first detector).

Results of experiments

Experiment №1

The initial traffic conditions:

— Value of volume: 2000 auth.
— Location of parking place: before 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450
Инц					137						305				
Статус		58	61	61	62	59	62	63	62	60	62	63	61	61	61
Кол-во	0	3	14	26	35	39	44	57	64	66	73	92	104	116	128
	0	3	12	23	29	32	37	47	57	60	71	92	105	113	120
	3	13	25	36	44	53	58	69	76	87	95	108	117	128	136
	2	12	24	35	41	48	54	65	71	83	90	102	111	119	127
Скорость		64,08	62,86	62,07	61,38	60,32	60,50	59,75	58,93	58,81	58,05	57,70	61,84	61,70	61,69
		61,08	61,19	60,75	61,00	59,85	59,18	58,79	57,85	57,02	56,08	55,24	60,87	60,86	60,96
	62,59	62,49	61,65	60,98	61,07	61,70	61,78	61,57	61,65	61,62	61,51	61,66	61,57	61,56	61,54
	64,03	62,40	61,61	61,64	61,63	61,49	61,31	61,10	61,13	61,06	61,29	61,00	61,01	61,06	61,18

Figure 9. The result of the algorithm operation (experiment #1)

At given traffic conditions algorithm it does not immediately determine the occurrence of the incident, resulting in time of incident detection is increased.

Table 1. The result of the experiment #1

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	73	1	0
2	70	1	0
3	61	1	0

4	45	1	0
5	67	1	0
6	50	1	0
7	71	1	0
8	71	1	0
9	57	1	0
10	68	1	0
Total	63,3	100%	0%

Experiment №2

The initial traffic conditions:

— Value of volume: 4000 auth.
— Location of parking place: before 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					148							345				
Статус		61	61	61	62	62	62	63	63	62	62	63	72	63	63	61
Кол-во	0	4	23	42	54	63	68	72	76	80	86	95	115	132	148	162
	0	6	24	46	54	65	78	92	106	113	121	138	155	170	185	201
	4	23	41	54	73	90	110	112	124	134	140	146	155	159	174	191
	5	26	46	60	78	96	117	121	128	136	145	153	163	175	187	201
Скорость		62,47	59,97	59,27	59,63	60,10	60,26	60,40	60,55	60,53	60,65	60,54	60,30	60,43	60,40	60,32
		63,29	59,80	58,95	59,19	59,68	59,74	60,15	60,25	60,36	60,61	60,66	60,71	60,66	60,61	60,56
	61,95	60,52	59,51	59,35	59,09	59,11	57,76	57,00	54,82	52,46	50,74	49,52	50,56	52,83	54,61	55,73
	65,48	59,85	59,67	60,13	59,89	59,84	58,39	57,18	55,21	53,52	51,81	50,37	50,32	52,00	53,36	55,39

Figure 10. The result of the algorithm operation (experiment #2)

The system showed the presence of the incident, when it was eliminated. It means that after the elimination of incident, traffic flow is not immediately come to the normal state (Klein, 2006). This situation would not be considered as a false alarm. A similar situation has arisen in other experiments.

Table 2. The result of the experiment #2

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	12	1	0
2	15	1	0
3	21	1	0
4	17	1	0
5	28	1	0
6	25	1	0
7	27	1	0
8	23	1	0
9	21	1	0
10	18	1	0
Total	20,7	100%	0%

Experiment №3

The initial traffic conditions:

— Value of volume: 8000 auth.
— Location of parking place: before 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540
Инц					138							345						
Статус		61	61	61	62	62	63	63	62	62	62	72	72	72	72	70	70	61
Кол-во	0	5	25	47	60	65	67	73	79	86	90	98	117	133	153	169	185	202
	0	6	26	48	61	80	94	103	113	121	129	148	167	182	197	214	229	247
	5	27	48	67	85	101	115	124	136	141	146	153	153	167	183	200	217	239
	5	27	48	67	89	107	124	127	134	145	153	165	174	183	199	214	232	253
Скорость		62,01	59,42	59,43	60,16	60,59	60,68	60,55	60,72	60,86	61,01	61,15	61,10	60,97	60,67	60,50	60,53	60,51
		62,53	59,59	58,64	59,12	59,68	59,85	60,04	60,17	60,20	60,34	60,47	59,97	59,93	60,00	60,01	60,04	60,08
	61,63	59,29	59,76	60,24	60,30	60,19	57,60	55,23	53,54	52,03	50,76	49,05	49,05	47,99	49,08	50,20	51,08	51,84
	65,31	60,26	59,34	58,28	58,14	58,50	56,27	55,11	52,87	50,87	49,17	47,06	45,38	44,41	45,60	46,72	47,75	48,69

Figure 11. The result of the algorithm operation (experiment #3)

Table 3. The result of the experiment #3

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	11	1	0
2	15	1	0
3	10	1	1
4	21	1	0
5	27	1	0
6	13	1	0
7	31	1	0
8	17	1	0
9	21	1	0
10	17	1	0
Total	18,3	100%	10%

In this experiment, the system showed a false alarm that incident occurred. This is because there were a large number of vehicles on the road, so average speed was below average given initially (60 km/h).

Experiment №4

The initial traffic conditions:

— Value of volume: 2000 auth.

— Location of parking place: in the middle.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					134						310					
Статус		58	61	61	61	61	62	62	62	60	62	62	62	61	63	61
Кол-во	0	3	14	26	35	39	43	50	55	59	65	79	90	102	114	121
	0	3	12	23	34	42	49	57	67	69	79	87	109	115	134	143
	3	13	25	36	44	53	58	69	76	87	95	108	117	128	136	144
	2	12	24	35	41	48	54	65	71	83	90	102	111	119	127	134
Скорость		64,08	62,86	62,07	61,42	61,52	61,52	61,99	62,04	62,10	62,04	62,10	62,19	61,99	61,95	61,95
		61,08	61,19	60,75	60,65	60,90	61,26	61,14	61,34	61,04	60,92	60,90	60,60	60,61	60,71	60,72
	62,59	62,49	61,65	60,98	61,06	61,58	61,75	60,44	59,45	59,24	58,03	57,18	59,13	61,16	61,16	61,29
	64,03	62,40	61,61	61,64	61,63	61,49	61,31	60,07	58,97	57,75	56,66	55,48	57,53	60,62	60,76	60,72

Figure 12. The result of the algorithm operation (experiment #4)

Table 4. The result of the experiment #4

#	Time of incident	Number of detected	The number of false

	detection (s)	incidents	alarms
1	69	1	0
2	75	1	0
3	61	1	1
4	54	1	0
5	30	1	0
6	67	1	0
7	69	1	0
8	74	1	0
9	70	1	0
10	71	1	0
Total	64	100%	10%

As in the experiment №1, system with low value of traffic volume does not immediately determine the occurrence of the incident. In addition, the system showed a false alarm when the incident has already been eliminated and normal traffic is restored.

Experiment №5

The initial traffic conditions:

— Value of volume: 4000 auth.
— Location of parking place: in the middle.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					136						330					
Статус		61	61	61	61	63	62	62	69	71	71	72	72	71	72	70
Кол-во	0	4	23	42	52	56	60	68	71	79	83	97	117	131	152	170
	0	6	24	46	59	73	88	96	99	111	123	139	145	161	187	212
	4	23	41	54	73	89	96	108	115	129	135	143	153	165	191	210
	5	26	46	60	78	96	101	110	118	125	136	140	152	169	185	200
Скорость		62,47	59,97	59,27	59,38	59,81	59,99	60,58	60,72	61,16	61,17	61,23	61,03	61,07	60,81	60,63
		63,29	59,80	58,95	59,35	59,46	59,52	59,88	59,76	59,80	60,13	60,13	60,07	59,92	59,89	59,94
	61,95	60,52	59,51	59,35	59,08	57,35	54,33	50,18	47,77	45,13	43,88	44,25	46,89	47,41	48,82	50,11
	65,48	59,85	59,67	60,13	59,80	57,66	55,33	52,38	50,27	48,36	46,16	46,31	46,06	47,29	48,43	49,22

Figure 13. The result of the algorithm operation (experiment #5)

Table 5. The result of the experiment #5

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	35	1	0
2	47	1	0
3	31	1	0
4	29	1	0
5	37	1	0
6	42	1	0
7	33	1	0
8	34	1	0
9	42	1	0
10	33	1	0
Total	36,3	100%	0%

Experiment №6

The initial traffic conditions:

— Value of volume: 8000 auth.
— Location of parking place: in the middle.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					135							350				
Статус		61	61	61	61	63	62	62	62	62	69	71	72	70	70	70
Кол-во	0	5	25	47	59	65	72	80	84	88	93	101	119	137	153	170
	0	6	26	48	68	81	90	97	103	107	115	122	142	159	171	189
	5	27	48	67	85	98	103	109	114	123	130	133	149	164	180	196
	5	27	48	67	89	105	112	122	128	138	147	156	171	189	205	222
Скорость		62,01	59,42	59,43	59,81	60,15	60,41	60,82	61,11	61,03	61,15	61,10	61,05	60,96	60,84	60,74
		62,53	59,59	58,64	58,96	59,38	59,84	60,07	60,05	60,07	60,07	60,41	60,32	60,16	60,08	60,05
	61,63	59,29	59,76	60,24	60,12	58,20	55,78	52,39	49,51	47,44	46,45	45,67	46,53	47,80	48,95	49,92
	65,31	60,26	59,34	58,28	58,14	55,89	54,04	51,34	47,77	45,18	44,83	43,57	43,35	46,59	47,75	48,71

Figure 14. The result of the algorithm operation (experiment #6)

Table 6. The result of the experiment #6

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	45	1	0
2	48	1	0
3	37	1	0
4	41	1	0
5	39	1	0
6	40	1	0
7	35	1	0
8	31	1	0
9	34	1	0
10	43	1	0
Total	39,3	100%	0%

Experiment №7

The initial traffic conditions:

— Value of volume: 2000 auth.
— Location of parking place: after 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					139							340				
Статус		58	61	61	61	61	63	57	62	62	62	63	71	70	70	70
Кол-во	0	3	14	26	37	41	75	52	59	64	69	76	91	103	115	122
	0	3	12	23	33	41	47	55	64	69	75	93	111	126	133	142
	3	13	25	36	44	53	61	73	80	91	97	107	115	126	134	142
	2	12	24	35	41	47	50	61	67	77	86	98	113	121	129	136
Скорость		64,08	62,86	62,07	61,15	61,33	61,45	61,71	61,77	61,98	62,14	62,22	61,91	61,78	61,76	61,77
		61,08	61,19	60,75	60,56	60,77	60,86	61,13	60,91	60,78	60,97	61,19	60,92	60,85	60,94	60,93
	62,59	62,49	61,65	60,98	59,77	59,96	59,37	57,30	56,50	53,82	52,29	49,72	48,47	49,61	50,30	51,04
	64,03	62,40	61,61	61,64	61,34	60,32	59,63	57,93	56,70	54,41	51,00	49,32	50,16	50,93	51,68	52,10

Figure 15. The result of the algorithm operation (experiment #7)

Table 7. The result of the experiment #7

#	Time of incident	Number of detected	The number of false

	detection (s)	incidents	alarms
1	71	1	0
2	69	1	0
3	68	1	0
4	55	1	0
5	63	1	0
6	69	1	0
7	72	1	0
8	65	1	0
9	63	1	0
10	58	1	0
Total	65,3	100%	0%

Experiment №8

The initial traffic conditions:

— Value of volume: 4000 auth.

— Location of parking place: after 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					137						330					
Статус		61	61	61	61	62	62	71	68	72	71	71	80	71	70	70
Кол-во	0	4	23	42	54	57	61	69	72	80	88	96	112	130	145	162
	0	6	24	46	60	74	81	87	90	109	115	126	138	161	183	200
	4	23	41	54	69	76	83	85	88	96	100	108	126	141	157	177
	5	26	46	60	79	87	98	107	111	130	140	154	169	187	204	222
Скорость		62,47	59,97	59,27	59,39	59,59	59,86	60,01	60,20	60,75	61,03	61,11	60,99	60,64	60,52	60,47
		63,29	59,80	58,95	59,39	59,31	59,65	59,97	59,98	60,12	60,13	60,26	60,27	60,33	60,13	60,07
	61,95	60,52	59,51	59,35	55,85	51,69	48,21	47,20	44,91	43,57	41,16	39,40	43,72	45,51	47,16	48,54
	65,48	59,85	59,67	60,13	54,43	52,40	49,33	46,96	44,17	42,95	39,83	37,55	44,79	46,17	47,26	48,28

Figure 16. The result of the algorithm operation (experiment #8)

Table 8. The result of the experiment #8

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	31	1	0
2	47	1	0
3	27	1	0
4	32	1	0
5	29	1	0
6	33	1	0
7	41	1	0
8	25	1	1
9	23	1	0
10	29	1	0
Total	31,7	100%	10%

Experiment №9

The initial traffic conditions:

— Value of volume: 8000 auth.

— Location of parking place: after 100 m.

Время	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480
Инц					130							340				
Статус		61	61	61	61	63	62	62	72	72	71	71	71	70	70	70
Кол-во	0	5	25	47	65	71	79	84	96	103	109	115	128	142	159	176
	0	6	26	48	68	79	81	87	107	119	123	135	156	172	184	206
	5	27	48	67	83	91	97	100	104	110	116	125	142	159	174	195
	5	27	48	67	89	96	107	119	127	135	143	157	168	186	213	235
Скорость		62,01	59,42	59,43	59,66	60,12	60,45	60,71	60,83	60,86	60,93	61,16	61,20	60,97	60,94	60,82
		62,53	59,59	58,64	58,96	59,40	59,53	59,70	59,82	59,95	60,00	60,03	59,96	59,88	59,78	59,79
	61,63	59,29	59,76	60,24	58,24	54,44	51,80	50,52	48,99	47,06	44,76	44,07	43,95	45,55	48,73	49,92
	65,31	60,26	59,34	58,28	58,10	55,67	52,45	50,45	49,65	47,88	46,95	46,66	45,55	46,46	48,43	50,32

Figure 17. The result of the algorithm operation (experiment #9)

Table 9. The result of the experiment #9

#	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	27	1	0
2	40	1	0
3	29	1	0
4	31	1	0
5	35	1	0
6	27	1	0
7	22	1	0
8	39	1	0
9	28	1	0
10	25	1	0
Total	30,3	100%	0%

Discussion

Analysis of simulation results

The maximum value of incident detection time was obtained at low value of road volume (2000 auth/h) with using the proposed algorithm. The minimum value of detection time was observed at high value of volume (8,000 auth/h) - 18.3 seconds. This is caused by that presence of incident will affect faster on traffic flow with high volume than with low value.

Some experimentation have shown false alarms of incidents. Two of them were at average value of volume - 4000 auth/h.At high value of volume system showed the presence of the incident after its elimination. This is because congestion isn't immediately disappeared after the elimination of the incident. The averaged data for all simulation experiments are shown in Table 10.

Table 10. Summary results of the experiments

Number of experiment	Time of incident detection (s)	Number of detected incidents	The number of false alarms
1	63,3	1	0
2	20,7	1	0
3	18,3	1	0,1
4	64	1	0,1
5	36,3	1	0
6	39,3	1	0
7	65,3	1	0
8	31,7	1	0,1

9	30,3	1	0
Total	41,02	100%	3,33%

In all the experiments, the proposed algorithm has shown high results in the number of detected incidents – 100% иrelatively low rate of errors – 3,33%. Despite the fact that at low value of volume the incident detection time was large, the average result over time– 41,02 s. Other words on the average proposed algorithm determines the occurrence of the incident for the two phases (each phases of the data collection and its analysis were 30 s), that in general it is also a good result.

The implementation of the algorithm for determining the incident priority and emergency service

When the system has shown that the incident occurred, it runs the algorithm to determine the priority of the incident (Nikolaev & Sapego, 2016). Apart from the fact that the algorithm determines the priority; it is also depending on the input data identifies the emergency services which necessary to eliminate the incident.

For each type of incident is necessary to define its subtypes for more exact definition of the incident priority and the emergency services. The following subtypes of incident is defined (Kim & Choi, 2001):

Table 11. Determination of the emergency services depending on the subtype of the incident

The subtype of the incident	The emergency services	
1.1. Malfunction of vehicle: a tire puncture, mechanical / electrical failure, overheating	Evacuator	
2.2. Hit an obstacle (without health damage)		
1.2. The presence of obstacles on the road (tree, etc)	Utility services	
2.1. Collision of vehicle without health damage, hit a stationary vehicles	Main Directorate for Road Traffic Safety (GIBDD)	
3.1. Ignition of vehicle	Main Directorate for Road Traffic Safety (GIBDD)	Fire department
3.2. Causing harm to health		Emergency medical services
3.3. Spills of hazardous substances		Ministry of Emergency Situations

Because the original data for the evaluation of incident occurrence uploaded to Excel file, so language for the implementation of the algorithm has been selected visual basic. The user form is shown in Figure 20 where it is possible to choose define the characteristics of the incident (in real these data come from different sources – see Figure 1).

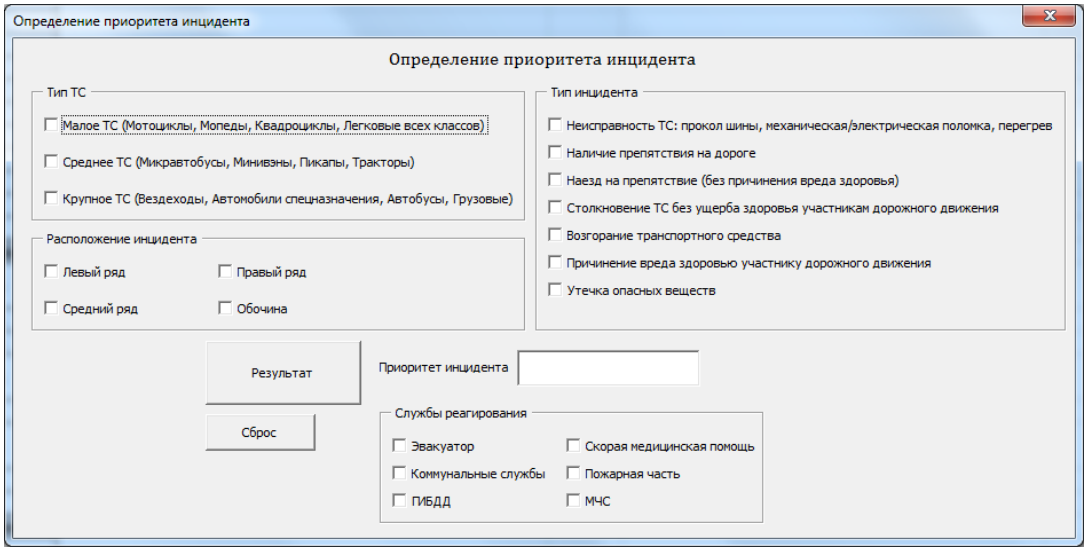

Figure 18. The user form to define the incident priority

In the pop-up form, it is possible to set several options for a particular parameter using Checkbox. For example, it is possible to set that the incident occurred on two lanes or cars and trucks involved in an incident, etc. This algorithm does not start if any of the parameter is not selected (additional window of error arise).

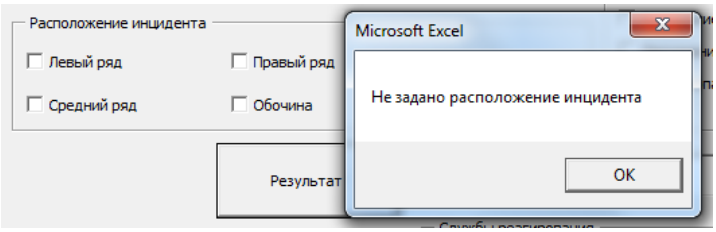

Figure 19. Error when the incident location not selected

When two options parameters are selected, the implemented algorithm will consider both parameters. Ultimately the maximum value will be set the corresponding variable. For example, priority is given to the incident occurred on the side of the road, will be lower than that of the incident, which occurred on the roadway. But if the incident took place on the roadway and on the shoulder, the priority will be given as if the incident occurred on the roadway. This logic applies to other parameters.

The exception-handling model is implemented in the algorithm. For example, in the proposed form it is not possible to choose the types of accidents where damage to health is and is not at the same time.

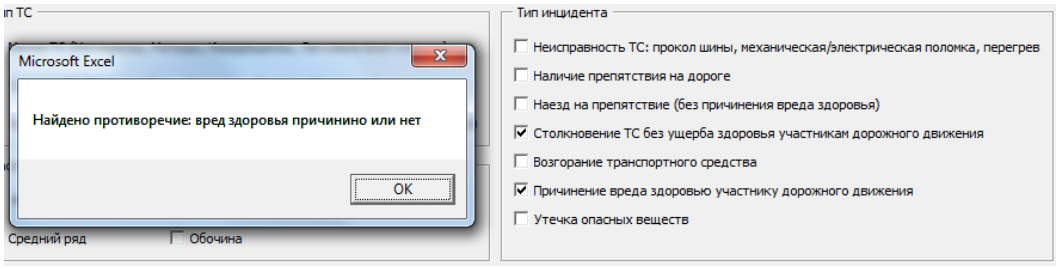

Figure 20. Error when choosing a couple of contradictory types of incidents

If all the necessary parameters are selected and the contradictions are not found then incident priority appears in the Textbox in the bottom of the form. In addition, there are emergency service below needed to resolve the incident (implemented using Checkbox).

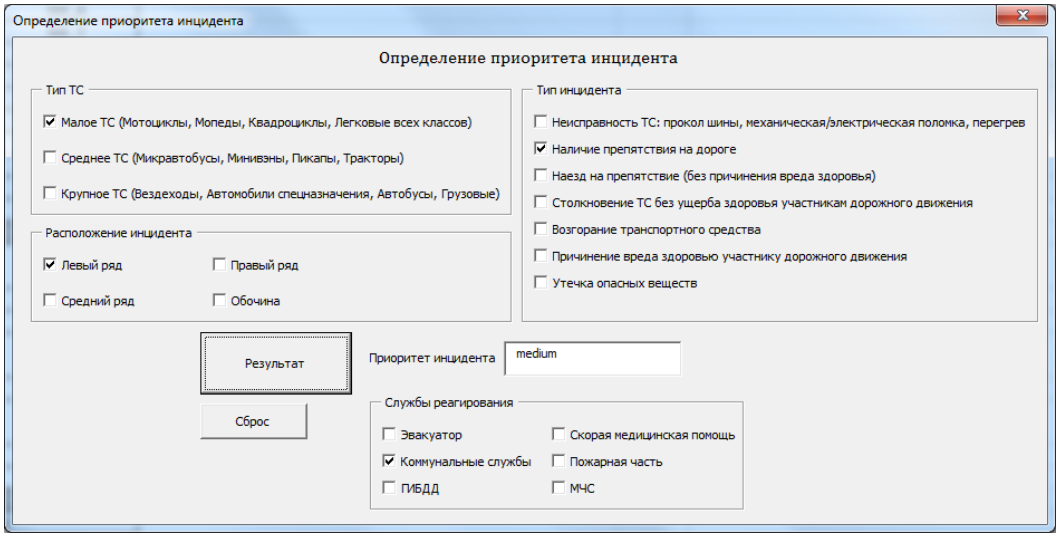

Figure 21. An example of algorithm operation №1

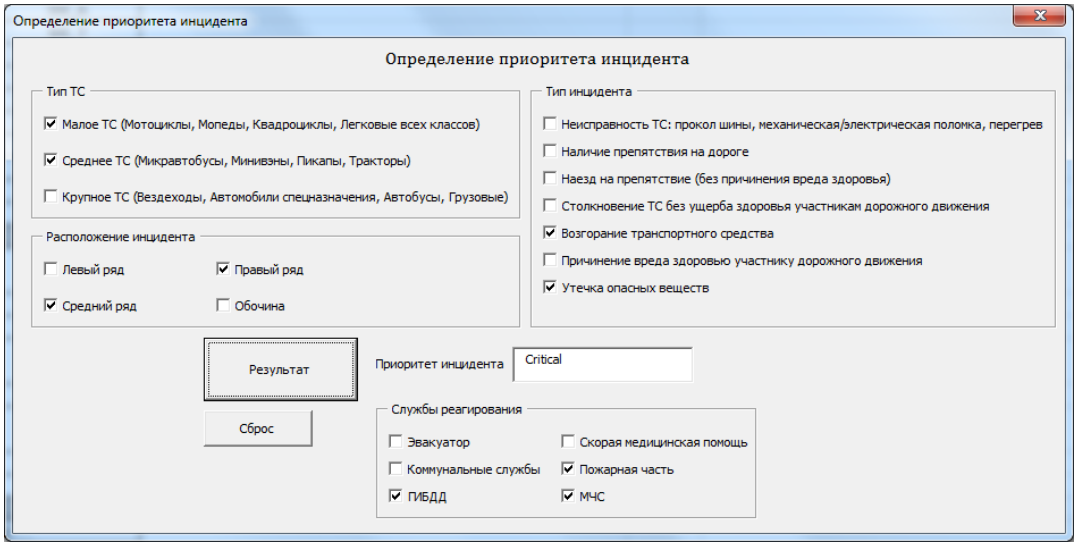

Figure 22. An example of algorithm operation №2

"Reset" button is used when it is necessary to set new parameters of the emerged incident and get a new priority.

Conclusions

In this article, it was modeled 9 different situations related to the occurrence of road accidents using PTV Vissim. In each experiment value of traffic volume (2000 auth/h, 4000 auth/h, 8000 auth/h) and value of incident (parking place) location (before 100m, between the sensors, after 100m) were changed. The proposed algorithm is implemented to determine the occurrence of incidents showed a good result - 100%. However, the algorithm was not the best indicator of false alarms – 3%.

In addition, an algorithm was proposed to determine the priority of the incident after its occurrence, implemented on visual basic. In addition to determining the priority, the algorithm also showed what emergency services should be notified to eliminate the incident.

Based on the results it can be concluded about the suitability of the proposed algorithm in the circuit of intelligent transport systems.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Andrey B. Nikolaev is Doctor of Technical Sciences, Professor, Head of Department at the Federal State Funded Educational Institution of Highest Education "Moscow Automobile and Road Construction State Technical University – MADI", Faculty of Management, Department of "Automated Control Systems", Moscow, Russia.

Yuliya S. Sapego is Postgraduate Student of the Federal State Funded Educational Institution of Highest Education "Moscow Automobile and Road Construction State Technical University – MADI", Faculty of Management, Department of "Automated Control Systems", Moscow, Russia.

Anatolij N. Jakubovich is Doctor of Technical Sciences, Professor at the Federal State Funded Educational Institution of Highest Education "Moscow Automobile and Road Construction State Technical University – MADI", Faculty of Management, Department of "Automated Control Systems", Moscow, Russia.

Leonid I. Berner Doctor of Technical Sciences, Professor, currently employed at JSC "AtlanticTransgasSystem", Moscow, Russia.

Andrey M. Ivakhnenko is Doctor of Tehcnical Sciences, Professor, Head of "Management" Department, Faculty of Logistic and Transportation Problems at the Federal State Funded Educational Institution of Highest Education "Moscow Automobile and Road Construction State Technical University – MADI", Moscow, Russia.

References

Akhmadieva, R.Sh. & Minnikhanov, R.N. (2015) Regional practice of developing road safety behavior competency in future specialists. *Journal of Sustainable Development, 8(3*), 242-249.

Akhmadieva, R.Sh. (2015) Competency development for safety measures on roads as a strategy for prevention of traffic accidents. *Mediterranean Journal of Social Sciences, 6(2S3)*, 176-181.

Alkandari, A. (2013). Accident Detection and Action System Using Fuzzy Logic Theory. *Proceedings of 2013 International Conference on Fuzzy Theory and Its Applica*tion. Taipei, Taiwan: National Taiwan University of Science and Technology, 385-390.

Bulat, P.V. & Volkov, K.N. (2016). Detonation Jet Engine. Part II – Construction Features. *International Journal of Environmental and Science Education, 11(12),* 5020-5033.

Deniz, O. & Celikoglub, H.B. (2011). Overview to some existing incident detection algorithms: a comparative evaluation. *Procedia - Social and Behavioral Sciences, 2*, 153-168.

Gettman, D., Pu, L., Sayed, T. & Shelby, S. (2008). *Surrogate Safety Assessment Model and Validation: Final Report*. Direct access: http://www.fhwa.dot.gov/publications/research/safety/-08051/08051.pdf

Gomes, G., May, A. & Horowitz, R. (2004). Calibration of VISSIM for a Congested Freeway. *California PATH Research Report*, *2*, 56-67.

GOST R 52398. The classification of highways. The main parameters and requirements (2005). Direct access: http://www.avtolikbez.ru/vardata/modules/lenta/images/2000-0/12409_1_1297373695.pdf

Hourdos, J. & Garg, V. (2008). *Michalopoulos P. Accident Prevention Based on Automatic Detection of Accident Prone Traffic Conditions*. Minnesota: University of Minnesota, 462 p.

Kim, H.J. & Choi, H.K (2001). A comparative analysis in incident service time on urban freeways. *IATSS RESEARCH, 25(1),* 62-72

Klein, L.A. (2006). *Traffic Detector*. Direct access: https://www.fhwa.dot.gov/publications/research/operations/its/06139/06139.pdf

Mahmassani, H.S., Haas, C., Zhou, S. & Peterman, J. (1999). *Evalution of incident detection methodologies.* Direct access: https://www.scholars.northwestern.edu/en/publications/evaluation-of-incident-detection-methodologies

Manstetten, D. & Maichle, J. (1996). Determination of traffic characteristics using fuzzy logic. *Vehicle Navigation and Information Systems Conference, VNIS'96,* 43 – 53.

Mitrovich, S., Valenti, G. & Mancini, M. (2006). A decision support system (DSS) for traffic incident management in roadway tunnel infrastructure. *RAIN Consortium – ENEA. Association for European Transport and contributors, 2,* 352-368.

Nikolaev, A.B. & Sapego, Y.S. (2015). Development of Traffic Accidents Control System. *Automation and Control in Technical Systems, 1,* 45-50, DOI: 10.12731/2306-1561-2015-1-6.

Nikolaev, A.B. & Sapego, Y.S. (2016). A Fuzzy approach to traffic accident control system. *Uniform All-Russia Scientific Bulletin*, 182-187.

Parkany, E.A (2005). Complete Review of Incident Detection Algorithms & Their Deployment: What Works and What Doesn't. *The New England Transportation Consortium, 1(112),* 267-274.

PTV optima and safety smart traffic control for smart cities (2014). Direct access: http://www.embarqturkiyeyasanabilirsehirler.org/sites/5270e7e07d0cca5c8a00e9b7/content_entry55b0a4075918ad5636000403/55b1f5205918adb62c000865/files/Sonal_Ahuja_PTV_OPTIMA_and_Safety_SMART_TRAFFIC_CONTROL_For_SMART_cities.pdf?1448878461

Simankov, V.S. & Shopin, A.B. (2004). Situational management complex object in conditions the fuzzy initial information. *Proceedings of the FOR A, 9*, 116-120.

Škorput, P., Mandžuka, S. & Jelušić, N. (2010). Real-time Detection of Road Traffic Incidents. *Promet – Traffic&Transportation, 22(4)*, 273-283.

Sultangazinov, S.K., Yessengarayev, B.S., Kainarbekov, A., Nauryzova, K.S. & Shagiachmetow, a.D.R. (2016). Working Capacity of Track Structure and Failure Simulation of its Components. *IEJME-Mathematics Education, 11(8)*, 2995-3008.

Tian, F. & Dong, H. (2012). Simulation of Traffic Incident Detection Based on VISSIM and Neural Network. *IEEE, 2(3),* 51-55.

Toymentseva, I.A., Karpova, N.P., Toymentseva, A.A., Chichkina, V.D. & Efanov, A.V. (2016). Methods of the Development Strategy of Service Companies: Logistical Approach. *International Journal of Environmental and Science Education, 11(14)*, 6820-6836.

Transport streams. (2016). The intensity and composition on the federal highway. Direct access: http://www.roads.ru/articles/a29_potoki.php

What keeps traffic flowing? (2016). Direct access: http://vision-traffic.ptvgroup.com/fileadmin/files_ptvvision/Downloads_N/0_General/2_Products/2_PTV_Vissim/BRO_PTV_Vissim_EN.pdf