Title

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Identification and evaluation of animal-vehicle collisions hotspots on highway M-18 in Ukraine by using graphical representation

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ABSTRACT:

We evaluate the deviation between the AVCs actual location in the road and model location that rounded up to a certain to character units as model location of AVC. The estimation of the deviation between actual location and model location is carried out for each of the models using three methods: a.) graphical analysis comparing the values models location on the single coordinate plane; b.) the comparison of their absolute and relative error; c.) the comparison of the class frequency for the values of the models locations.

Keywords:

Model location, animal-vehicle collisions, monitoring system, identification of hotspots, evaluation deviation

Introduction

Animal–vehicle collisions (AVCs) are a serious problem that can result in property damage and human and animal injury and death that increased the importance of studies of AVC locations (Jensen et. al., 2014; Huijser et.al., M. P., 2007). Such consequences are requires for building of predictive model for AVCs that has temporal and spatial components (Rodríguez-Morales et.al., 2013) as part of the monitoring system that has been used for identification of spatial clustering of AVC a long period of time (Diaz-Varela et.al., 2011). The predictive models with reliable statistical evaluation and accuracy can be generated from government databases. (Snow et.al., 2015). If the database has AVCs location with errors in records are realistic problems that often compromise accuracy of safety model outcomes. (Tegge and Ouyang ., 2008). The identification of crash hotspots is the first step of the highway safety management process. Errors in hotspot identification may result in the inefficient use of resources for safety improvements and may reduce the global effectiveness of the safety management process (Montella, 2010). The high-risk locations or hotspots for detailed engineering study and countermeasure evaluation is the first step in a transport safety improvement program (Miranda-Moreno, 2007). Systematically collected animal-vehicle collision data help estimate the magnitude of the problem and help record potential changes in animal-vehicle collisions over time. Such data also allow for the identification and prioritization of locations that has to require mitigation. Furthermore, systematically collected animal-vehicle collision data allow for the evaluation of the effectiveness of mitigation measures in reducing the number of animal-vehicle collisions (Huijser , 2007). To implement the previous provisions regarding the management and reduction of AVC is needed to developed a system of monitoring AVC, which includes the following principles (Erickson, 2007; Pettler, Amy et al.,2007) The article proposes to add to statistic methods for evaluate of identification of AVC (Lord and Mannering, 2010; Mannering and Chandra, 2014), the another method that are not popular in AVC's researches. It is graphical method of identifying of hotspots of AVC by using the graphical representation of which is investigated in our article and can be a tool for monitoring system for AVCs. After the AVC, there are some deviation determining of its location (Gunson, 2004). The study has another important issue to [illegible] deviation of AVC's location. The graphical methods can use in the monitoring systems for AVC. The monitoring system with only database is limited in using its full function for monitoring. The authors have proposed to improve of the functionality of the monitoring system by using a graphical representation of AVC data. There are some problems with choice of the graphical representation of AVC data that has been solved by using of evaluation method of the deviation graphical representation of the model location AVC as additional tool for monitoring. The present study is developing a graphical representation of AVCs model location by using evaluation of the deviation between the actual location l_{0_i} AVC on the road and its model location l_{n_i}. Each of AVC in the road has its own individual number N_{0_i} that is corresponding to the own value of the location l_{0_i} on the road. Figure 1 shows the graph of distribution 79 points of AVC that they have actual values of the locations l_{0_i} and individual number N_{0_i}, where *i* - count of AVC if *i*=79 the graph cannot be fully reflected all points of the values actual locations l_{0_i} for each AVC. After rounding of the values actual location l_{0_i}, that were obtained in the model location l_{n_i} where *n=1;2;3;4* number of models for rounding: a.) numbers to the nearest 100 in the model *n=1*; (b.) numbers to the nearest 1000 in the model *n=2*; (c.) numbers to the nearest 10000 in the model *n=3*; d.) numbers to the nearest 100000 in the model *n=4*. For each *n*-models is proposed to evaluate the value of deviations $\lvert l_{0_i} - l_{n_i} \rvert$, using the following three methods: 1.) graphical analysis comparing the values models location l_{1_i}, l_{2_i}, l_{3_i}, l_{4_i} on the one coordinate plane; 2.) evaluation of their absolute $\Delta\left(l_n'\right)$ and relative error $\delta\left(l_n'\right)$ 3.) evaluate of the class frequency f_n and of the width of the class frequency h_n from f_n after grouping numeric data by intervals 100,1000,10000, 100000 for each of the *n*-models locations.

These methods are basis of graphic to represent data and authors propose add to monitoring system which has already temporal and spatial components. The article is represented of development principal of graphical representation AVCs as a part of the monitoring system. For this will be evaluated deviation between the value of the real location l_{0_i} AVC on the road and its rounded value model location l_{n_i}.

Method

The study used AVC data *i*=79 which have place in period from 18.12.2007 to 23.12.2013 on the highway M-18 in Zaporozhye region of Ukraine. Every AVC has its own individual number N_{0_i} and appropriate of value of the real location of the accident L_{0_i} was expressed in kilometres and metres from AVC government database. The values of L_{0_i} has transformed into values l_{0_i} that expressed only meters. In the Microsoft Excel values l_{0_i} was rounded to values - l_{n_i}, where *n* - is the number of model location: for *n =1* model location is l_{1_i}

; for *n =2* model location is l_{2_i}; for *n =3* model location is l_{3_i} ; *n =4* model location is l_{4_i} .

The value of L_{0_i}, l_{0_i} and l_{n_i} were included in a calculation table where each records L_{0_i} has an individual number to identification AVC N_{0_i}. The calculation table has the following columns: N_{0_i} - individual number of AVC; L_{0_i}, - reallocation of AVC from the database of AVC of the State traffic police Zaporozhye and which expressed in kilometers and meters, l_{0_i0} - copy column " L_{0_i} " which is transformed into only meters; l_{1_i} −¿ the value of the location after rounding l_{0_i} for *n=1*; l_{2_i} - the value of the location after rounding l_{0_i} for *n=2*; l_{3_i} - the value of the location after rounding l_{0_i} for *n=3*; l_{4_i} - the value of the location after rounding l_{0_i} for *n=4*. The data for all model location *n=1,2,3,4* are summarized in Table 1.

Table1.Calculation table for the values of the location l_{0_i} accident and after rounding to the values of the model location l_{1_i}, l_{2_i} , l_{3_i} , l_{4_i}

	L_{0_i}	l_{0_i}	l_{1_i}	l_{2_i}	l_{3_i}	l_{4_i}
1	260 km 250 m	260250	260300	260000	260000	300000
2	262 km 800 m	262800	262800	263000	260000	300000
3	268 km 100 m	268100	268100	268000	270000	300000
4	270 km 970 m	270970	271000	271000	270000	300000
5	271 km 970 m	271970	272000	272000	270000	300000
6	274 km 600 m	274600	274600	275000	270000	300000
7	277 km 900 m	277900	277900	278000	280000	300000
8	278 km 070 m	278070	278100	278000	280000	300000
9	279 km 800 m	279800	279800	280000	280000	300000
10	280 km 300 m	280300	280300	280000	280000	300000
11	280 km 790 m	280790	280800	281000	280000	300000
12	282 km 700 m	282700	282700	283000	280000	300000
13	283 km 150 m	283150	283200	283000	280000	300000
14	284 km 200 m	284200	284200	284000	280000	300000
15	286 km 800 m	286800	286800	287000	290000	300000
16	290 km 150 m	290150	290200	290000	290000	300000
17	290 km 700 m	290700	290700	291000	290000	300000
18	291 km 040 m	291040	291000	291000	290000	300000
19	291 km 400 m	291400	291400	291000	290000	300000
20	292 km 150 m	292150	292200	292000	290000	300000
21	292 km 850 m	292850	292900	293000	290000	300000
22	292 km 500 m	292500	292500	293000	290000	300000
23	292 km 950 m	292950	293000	293000	290000	300000
24	293 km 800 m	293800	293800	294000	290000	300000
25	294 km 050 m	294050	294100	294000	290000	300000
26	294 km 070 m	294070	294100	294000	290000	300000
27	295 km 900 m	295900	295900	296000	300000	300000
28	295 km 050 m	295050	295100	295000	300000	300000
29	296 km 200 m	296200	296200	296000	300000	300000
30	296 km 250 m	296250	296300	296000	300000	300000
31	296 km 450 m	296450	296500	296000	300000	300000
32	297 km 290 m	297 290	297300	297000	300000	300000
33	297 km 700 m	297 700	297700	298000	300000	300000
34	297 km 087 m	297 087	297100	297000	300000	300000
35	299 km 150 m	299150	299200	299000	300000	300000
36	300 km 150 m	300150	300200	300000	300000	300000
37	302 km 900 m	302900	302900	303000	300000	300000
38	303 km 015 m	303015	303000	303000	300000	300000
39	303 km 500 m	303500	303500	304000	300000	300000
40	303 km 800 m	303800	303800	304000	300000	300000
41	303 km 400 m	303400	303400	303000	300000	300000
42	304 km 650 m	304650	304700	305000	300000	300000
43	313 km 570 m	313570	313600	314000	310000	300000
44	318 km 770 m	318770	318800	319000	320000	300000
45	321 km 300 m	321300	321300	321000	320000	300000
46	322 km 830 m	322830	322800	323000	320000	300000
47	323 km 860 m	323860	323900	324000	320000	300000
48	325 km 470 m	325470	325500	325000	330000	300000
49	325 km 600 m	325600	325600	326000	330000	300000
50	325 km 720 m	325720	325700	326000	330000	300000
51	330 km 321 m	330321	330300	330000	330000	300000
52	333 km 410 m	333410	333400	333000	330000	300000
53	337 km 120 m	337120	337100	337000	340000	300000
54	337 km 080 m	337080	337100	337000	340000	300000
55	338 km 800 m	338800	338800	339000	340000	300000
56	338 km 830 m	338830	338800	339000	340000	300000
57	339 km 495 m	339495	339500	339000	340000	300000
58	340 km 650 m	340650	340700	341000	340000	300000
59	344 km 100 m	344100	344100	344000	340000	300000
60	347 km 290 m	347290	347300	347000	350000	300000
61	353 km 500 m	353500	353500	354000	350000	400000
62	353 km 946 m	353946	353900	354000	350000	400000
63	367 km 920 m	367920	367900	368000	370000	400000
64	377 km 710 m	377710	377700	378000	380000	400000
65	386 km 900 m	386900	386900	387000	390000	400000
66	396 km 600 m	396600	396600	397000	400000	400000
67	398 km 700 m	398700	398700	399000	400000	400000
68	400 km 300 m	400300	400300	400000	400000	400000
69	402 km 800 m	402800	402800	403000	400000	400000
70	404 km 600 m	404600	404600	405000	400000	400000
71	404 km 600 m	404600	404600	405000	400000	400000
72	417 km 850 m	417850	417900	418000	420000	400000
73	419 km 850 m	419850	419900	420000	420000	400000
74	431 km 130 m	431130	431100	431000	430000	400000
75	433 km 450 m	433450	433500	433000	430000	400000
76	443 km 080 m	443080	443100	443000	440000	400000
77	449 km 850 m	449850	449900	450000	450000	400000
78	453 km 022 m	453022	453000	453000	450000	500000
79	454 km 000 m	454000	454000	454000	450000	500000

To evaluation the deviation between the value actual location l_{0_i} and value model location l_{n_i} were used the following methods: 1.) the graphic analysis comparing the values of the point of models location l_{1_i} , l_{2_i} , l_{3_i}, l_{4_i} on the one coordinate plane; 2.) the comparison of their absolute $\Delta(l'_{n_i})$ and relative error $\delta(l'_{n_i})$; c.) the comparison of the class frequency f_n for the values of the models locations and the width of the class frequency h_n after grouping numeric data by intervals *100,1000,10000, 100000* for each of the *n*-models locations.

1.) For the first evaluation method: graphical analysis comparing the values l_{n_i} , for columns l_{1_i} , l_{2_i} , l_{3_i}, l_{4_i} from Table 1 were constructed graphs of distribution of point of models location of AVC on each coordinate plane for *n=1,2,3,4* (Fig. 2,3,4,5).

Individual number of AVC,

Fig.2 Graph with a points of the distribution of values of model locations l_{1_i} for *n=1*

ndividual number of AVC,

Fig.3 Graph with a point of the distribution of values of model locations l_{2_i} for *n=2*

Individual number of AVC,

Fig.4 Graph with a point of the distribution of values of model locations l_{3_i} for n=3.

Individual number of AVC,

Fig.5 Graph with a point of the distribution of values of model locations l_{1_i} for n=4.

2.) The second method of evaluation of the deviation between l_{0_i} and l_{n_i} using the calculations of the absolute error $\Delta(l'_{n_i})$ and relative error $\delta(l'_{n_i})$ was prepared in the Table 2.The calculation of the absolute error $\Delta(l'_{n_i})$ and relative error $\delta(l'_{n_i})$ for is held by the formulas (2) and (3):

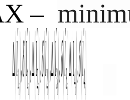
$$\Delta(l'_{n_i}) = ¿ l_{n_i} - l_{0_i} \vee ¿ \tag{2}$$

$$\delta(l'_{n_i}) = ¿ \frac{¿ l_{n_i} - l_{0_i} \vee ¿}{l_{n_i}} \tag{3}$$

Table 2. Calculation of the absolute error $\Delta(l'_{n_i})$ and relative error $\delta(l'_{n_i})$ for *n*-models.

N.	$\Delta($	$\delta(l$	$\Delta($	$\delta(l$	$\Delta($	$\delta(l$	$\Delta($	$\delta(l'$
1	50	0,0002	250	0,0010	250	0,0010	39750	0,1527
2	0	0,0000	200	0,0008	2800	0,0107	37200	0,1416
3	0	0,0000	100	0,0004	1900	0,0071	31900	0,1190
4	30	0,0001	30	0,0001	970	0,0036	29030	0,1071
5	30	0,0001	30	0,0001	1970	0,0072	28030	0,1031
6	0	0,0000	400	0,0015	4600	0,0168	25400	0,0925
7	0	0,0000	100	0,0004	2100	0,0076	22100	0,0795

8	30	0,0001	70	0,0003	1930	0,0069	21930	0,0789
9	0	0,0000	200	0,0007	200	0,0007	20200	0,0722
10	0	0,0000	300	0,0011	300	0,0011	19700	0,0703
11	10	0,0000	210	0,0007	790	0,0028	19210	0,0684
12	0	0,0000	300	0,0011	2700	0,0096	17300	0,0612
13	50	0,0002	150	0,0005	3150	0,0111	16850	0,0595
14	0	0,0000	200	0,0007	4200	0,0148	15800	0,0556
15	0	0,0000	200	0,0007	3200	0,0112	13200	0,0460
16	50	0,0002	150	0,0005	150	0,0005	9850	0,0339
17	0	0,0000	300	0,0010	700	0,0024	9300	0,0320
18	40	0,0001	40	0,0001	1040	0,0036	8960	0,0308
19	0	0,0000	400	0,0014	1400	0,0048	8600	0,0295
20	50	0,0002	150	0,0005	2150	0,0074	7850	0,0269
21	50	0,0002	150	0,0005	2850	0,0097	7150	0,0244
22	0	0,0000	500	0,0017	2500	0,0085	7500	0,0256
23	50	0,0002	50	0,0002	2950	0,0101	7050	0,0241
24	0	0,0000	200	0,0007	3800	0,0129	6200	0,0211
25	50	0,0002	50	0,0002	4050	0,0138	5950	0,0202
26	30	0,0001	70	0,0002	4070	0,0138	5930	0,0202
27	0	0,0000	100	0,0003	4100	0,0139	4100	0,0139
28	50	0,0002	50	0,0002	4950	0,0168	4950	0,0168
29	0	0,0000	200	0,0007	3800	0,0128	3800	0,0128
30	50	0,0002	250	0,0008	3750	0,0127	3750	0,0127
31	50	0,0002	450	0,0015	3550	0,0120	3550	0,0120
32	10	0,0000	290	0,0010	2710	0,0091	2710	0,0091
33	0	0,0000	300	0,0010	2300	0,0077	2300	0,0077
34	13	0,0000	87	0,0003	2913	0,0098	2913	0,0098
35	50	0,0002	150	0,0005	850	0,0028	850	0,0028
36	50	0,0002	150	0,0005	150	0,0005	150	0,0005
37	0	0,0000	100	0,0003	2900	0,0096	2900	0,0096
38	15	0,0000	15	0,0000	3015	0,0100	3015	0,0100
39	0	0,0000	500	0,0016	3500	0,0115	3500	0,0115
40	0	0,0000	200	0,0007	3800	0,0125	3800	0,0125
41	0	0,0000	400	0,0013	3400	0,0112	3400	0,0112
42	50	0,0002	350	0,0011	4650	0,0153	4650	0,0153
43	30	0,0001	430	0,0014	3570	0,0114	13570	0,0433
44	30	0,0001	230	0,0007	1230	0,0039	18770	0,0589
45	0	0,0000	300	0,0009	1300	0,0040	21300	0,0663
46	30	0,0001	170	0,0005	2830	0,0088	22830	0,0707
47	40	0,0001	140	0,0004	3860	0,0119	23860	0,0737
48	30	0,0001	470	0,0014	4530	0,0139	25470	0,0783
49	0	0,0000	400	0,0012	4400	0,0135	25600	0,0786
50	20	0,0001	280	0,0009	4280	0,0131	25720	0,0790
51	21	0,0001	321	0,0010	321	0,0010	30321	0,0918
52	10	0,0000	410	0,0012	3410	0,0102	33410	0,1002
53	20	0,0001	120	0,0004	2880	0,0085	37120	0,1101
54	20	0,0001	80	0,0002	2920	0,0087	37080	0,1100
55	0	0,0000	200	0,0006	1200	0,0035	38800	0,1145
56	30	0,0001	170	0,0005	1170	0,0035	38830	0,1146
57	5	0,0000	495	0,0015	505	0,0015	39495	0,1163
58	50	0,000	350	0,0010	650	0,0019	40650	0,1193
		1						
59	0	0,0000	100	0,0003	4100	0,0119	44100	0,1282
60	10	0,0000	290	0,0008	2710	0,0078	47290	0,1362
61	0	0,0000	500	0,0014	3500	0,0099	46500	0,1315
62	46	0,0001	54	0,0002	3946	0,0111	46054	0,1301
63	20	0,0001	80	0,0002	2080	0,0057	32080	0,0872
64	10	0,0000	290	0,0008	2290	0,0061	22290	0,0590
65	0	0,0000	100	0,0003	3100	0,0080	13100	0,0339
66	0	0,0000	400	0,0010	3400	0,0086	3400	0,0086
67	0	0,0000	300	0,0008	1300	0,0033	1300	0,0033
68	0	0,0000	300	0,0007	300	0,0007	300	0,0007
69	0	0,0000	200	0,0005	2800	0,0070	2800	0,0070
70	0	0,0000	400	0,0010	4600	0,0114	4600	0,0114
71	0	0,0000	400	0,0010	4600	0,0114	4600	0,0114
72	50	0,0001	150	0,0004	2150	0,0051	17850	0,0427
73	50	0,0001	150	0,0004	150	0,0004	19850	0,0473
74	30	0,0001	130	0,0003	1130	0,0026	31130	0,0722
75	50	0,0001	450	0,0010	3450	0,0080	33450	0,0772
76	20	0,0000	80	0,0002	3080	0,0070	43080	0,0972
77	50	0,0001	150	0,0003	150	0,0003	49850	0,1108
78	22	0,0000	22	0,0000	3022	0,0067	46978	0,1037
79	0	0,0000	0	0,0000	4000	0,0088	46000	0,1013
MIN	**0**	**0,0000**	**0**	**0,0000**	**150**	**0,0333**	**150**	**0,0500**
MAX	**50**	**0,0192**	**500**	**0,1709**	**4950**	**1,6777**	**49850**	**15,2738**

Note: MIN and MAX – minimum and maximum values that selected from 

3.) The third method evaluation of the deviation between l_{0_i} and l_{n_i} by calculating the class frequency f_n for the values of the model locations l_{1_i}, l_{2_i}, l_{3_i}, l_{4_i} and of the width of the interval grouped h_n for *n=1,2,3,4* that are presented in Table 3.

Table 3. Class frequency f_n, for models *n*.

Number of models, *n*	*1*	*2*	*3*	*4*
Class frequency, f_n	75	60	19	3
Amount of AVC, i	79	79	79	79

For each group l_{n_i} for *n*-models create the distribution graph of the class frequency f_n for model location l_{n_i} (Fig.6,7,8,9). Graph of the group for the model l_{1_i} shown in Fig. 6.

Figure 6. The graph of the distribution of the class frequency f_1 for model locations l_{1_i} for n=1.

The graph of the distribution of the class frequency f_2 for locations l_{2_i} for n=2 shown in Figure 7.

Figure 7. The graph of the distribution of the class frequency f_2 for model location l_{2_i} for *n=2.*

The graph of the distribution of the class frequency f_3 for locations l_{3_i} for *n=3* shown in Figure 8.

Figure 8. The graph of the distribution of the class frequency f_3 for model location l_{3_i} for *n=3.*

The graph of the distribution of the class frequency f_4 for locations l_{4_i} for *n=4* shown in Figure 9.

Figure 9. The graph of the distribution of the class frequency f_4 for the model locations l_{4_i} for *n=4.*

Result:

a.) Graphical analysis on the coordinate plane graphs of the distributions of the values of the models locations l_{1_i}, l_{2_i}, l_{3_i}, l_{4_i} from individual accidents N_{0_i} in Figure 10.

Fig 10. Graphical analysis on the coordinate plane graphs with points of the distributions of the values of the models locations l_{1_i}, l_{2_i}, l_{3_i}, l_{4_i}

Model location of AVC, l_{n_i} N_{0_i}. Note: Figure

and $l_{4_{79}}$ for

N

models locations 4_i.

The second evaluation method on the coordinate plane graphs of the relative error $\delta(l_1')$, $\delta(l_2')$, $\delta(l_3')$, $\delta(l_4')$ for *n*-models in shows in Figure 11. There are very significant difference data for the absolute error $\Delta(l_n')$) for *n=1* and *n*=4 they were not Model location l_{2_i} ven in Tab

Fig. for

each of the individual numbers of AVCs N_{0_i}

$\delta(l'$

N_0

3.) The third method evaluation of the deviation between l_{0_i} and l_{n_i} was calculated the f_n – class frequency are grouped by the value model locations l_{1_i}, l_{2_i}, l_{3_i}, l_{4_i}, from the Table 2, and the width of the class frequency h_n, grouping numeric data by intervals 100,1000,10000, 100000 for each of *n=1;2;3;4* are presented in Table 4. To calculate the class frequency h_n, for each *n*-model using Formula 3.

$$h_n = \frac{N_{max}-N_{min}}{N_n} \quad (3)$$

where h_n - class interval; f_n – class frequency; N_{max} - upper class limit at the groups AVC, from Table 4 for each *n*; N_{min} - lower class limit value of the amount at the groups AVC, from the Table 4 for each *n*. Data for calculating the width of the interval grouping for each model are given in Table 4.

Table 4. Calculation of the class interval h_n *from* class frequency f_n for *n*-models

n	1	2	3	4
Upper class limit, N_{max}	2	3	16	60
Lower class limit, N_{min}	1	1	1	2
Range, $N_{max}-N_{min}$,	1	2	15	58
Class frequency, f_n	75	60	19	3
Count of AVC, N_{0_i}	79	79	79	79
Class interval, h_n	0,013	0,033	0,789	19,333

Graph of the dependence for the class interval h_n from class frequency f_n for *n*-models are shown in Figure 12.

Figure 12. Graph of the of the dependence of the class interval h_n from class frequency f_n for *n*-models

The evaluation results of the *n*-models ıre shown in Table 5 for models *n=1,2,3,4*

Table 5. The evaluation results of the three methods for models *n=1,2,3,4*

n	1	2	3	4
Upper class limit, N_{max}	2	3	16	60
Lower class limit, N_{min}	1	1	1	2
Range, $N_{max}-N_{min}$,	1	2	15	58
Class frequency, f_n	75	60	19	3
Count of AVC, N_{0_i}	79	79	79	79
Class interval, h_n	0,013	0,033	0,789	19,333
Absolute error, Min, $\Delta(l'_{n_i})$	0	0	150	150
Absolute error, Max, $\Delta(l'_{n_i})$	50	500	4950	49850
Relative error, Min,	0,000	0,000	0,033	0,050

$\delta\left(l'_{n_i}\right)$				
Relative error, Max, $\delta\left(l'_{n_i}\right)$	0,0192	0,1709	1,6777	15,2738

Discussion

1. The graphs of the animal–vehicle collisions (AVC) для models location має next values:

- for model location l_{1_i} in the next distance of the graphs there are:

in the distance *250000*≤ l_{1_i} ≤*300000* the AVC individual numbers are *1* $\leq N_{0_i}$ ≤*36* and AVC count is *i=36*;

in the distance *300000*≤ l_{1_i} ≤*350000* the AVC individual numbers are *37* $\leq N_{0_i}$ ≤*61* and AVC count is *i=25*;

in the distance *350000*≤ l_{1_i} ≤*400000* the AVC individual numbers are *62* $\leq N_{0_i}$ ≤68 and AVC count is *i=7*;

in the distance *400000*≤ l_{1_i} ≤*450000* the AVC individual numbers are *69* $\leq N_{0_i}$ ≤*79* and AVC count is *i=9*.

Total count AVC is *i=79* for model location l_{1_i}.

The model location l_{1_i} is have enough of count AVC individual numbers in the monitoring systems graph. But not all the points can be seen on the AVC graph.

- for model location l_{2_i} :

in the distance *250000*≤ l_{1_i} ≤*300000* the AVC individual numbers are *1* $\leq N_{0_i}$ ≤*36* and AVC count is *i=36*;

in the distance *300000*≤ l_{1_i} ≤*350000* the AVC individual numbers are *37* $\leq N_{0_i}$ ≤*62* and AVC count is *i=26*;

in the distance *350000*≤ l_{1_i} ≤*400000* the AVC individual numbers are *63* $\leq N_{0_i}$ ≤*68* and AVC count is *i=6*;

in the distance *400000*≤ l_{1_i} ≤*450000* the AVC individual numbers are *69* $\leq N_{0_i}$ ≤*79* and AVC count is *i=11*.

Total count AVC is *i=79* for model location l_{2_i}.

The model location l_{2_i} is have enough of count AVC individual numbers in the monitoring systems graph. But not all the points can be seen on the AVC graph.

- for model location l_{3_i} :

in the distance *250000*≤ l_{1_i} ≤*300000* the AVC individual numbers are *1* $\leq N_{0_i}$ ≤42 and AVC count is *i=42*;

in the distance *300000*≤ l_{1_i} ≤*350000* the AVC individual numbers are *43* $\leq N_{0_i}$ ≤*62* and AVC count is *i=20*;

in the distance *3500000*≤ l_{1_i} *≤400000* the AVC individual numbers are *63* $\le N_{0_i}$ *≤71*and AVC count is *i=9*;

in the distance *400000*≤ l_{1_i} *≤450000*the AVC individual numbers are *72* $\le N_{0_i} \le$ *79* and AVC count is *i=8;*

Total count AVC is *i=79* for model location l_{3_i} .

The model location l_{3_i} has enough of count AVC individual numbers in the monitoring systems graph. All the points can be seen on the AVC graph.

- for model location l_{4_i} :

in the distance *250000*≤ l_{1_i} *≤300000* the AVC individual numbers are *1* $\le N_{0_i} \le$ *60* and AVC count is *i=60*;

in the distance *300000*≤ l_{1_i} *≤350000* the AVC individual numbers are 6*1* $\le N_{0_i} \le$ *77* and AVC count is *i=17*;

in the distance *350000*≤ l_{1_i} *≤400000* the AVC individual numbers are 7*8* $\le N_{0_i}$ *≤79* and AVC count is *i=2*;

Total count AVC is *i=79* for model location l_{4_i} .

The model location l_{4_i} has very small point in the AVC monitoring systems graph. All the points can be seen on the AVC graph.

2. The graphs of values relative error $\delta\left(l'_n\right)$ for models locations is $0 \le \delta\left(l'_{1_i}\right) \le 1; 0 \le \delta\left(l'_{2_i}\right) \le 1; 0 \le \delta\left(l'_{3_i}\right) \le 2$; *0* $\le \delta\left(l'_{4_i}\right) \le$ *16.* The models location l_{1_i}, l_{2_i}, l_{3_i} is accurate for monitoring systems graph. The model location l_{4_i} is inaccurate for monitoring systems graph.

3. The graphs of the distribution of the class frequency f_1 for model location l_{1_i} has the following values: lower class limit N_{min} = 1, upper class limit N_{max} =2 in the next point of models location l_{1_i}: *290100, 337100, 404600* The graphs of the distribution of the class frequency f_2 per model location l_{2_i} has the following values: lower class limit N_{min} = 1, upper class limit N_{max} =3 in the next point of models location l_{2_i}: *290100, 339000.* The graphs of the distribution of the class frequency f_3 per model location l_{3_i} has the following values: lower class limit N_{min} = 1, upper class limit N_{max} =16 and the next class frequency: f_3 =16 in the point of model location is $l_{3_i}=300000;$ f_3 =7 in the point

of model location $l_{3_i}=340000;$ f_3 =6 in the point of model location $l_{3_i}=400000;$ f_3 =3 in the point of model location $l_{3_i}=450000.$ The graphs of the distribution of the class frequency f_4 for model location l_{4_i} has the following values: lower class limit N_{min} = 1, upper class limit N_{max} =60 and the next class frequency: f_4 =60 in the point of model location is $l_{3_i}=300000;$ f_4 =17 in the point of model location $l_{4_i}=400000;$ f_3 =2 in the point of model location $l_{3_i}=500000.$ The class interval for *1,2,3*-models is h_n ≤ 1 that is an acceptable result for monitoring systems. The class interval for 4-models is h_n *=19,3* that is an unacceptable result for monitoring systems.

Conclusions

Four models location can be used in the monitoring system as four modes, ranging from n = 1 as "minimal deviation and minimum class frequency " and ending with n = 4 as "maximum deviation and maximum class frequency . Using the n = 1 "minimum deviation and minimum class frequency " allows to use monitoring of the animal vehicle collisions that has approach to the real location, and in case n = 4 deviation of location - has a maximum value and maximum concentration of point. In the case *n = 4* mode as "maximum deviation and maximum class frequency f_n " has count of class frequency f_n the minimum value that makes it impossible use the graph in the monitoring system the number of locations AVC, allowing to identify the location on the highway, where the greatest number of hot spots of animal–vehicle collisions in the road M-18 in Ukraine. Deviations between l_{0_i} and l_{n_i} in models location *n*=2 and *n*=3 are the most optimal to represent the value of the location l_{n_i} as the characteristics of the AVC monitoring system.

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